ASSESSMENT OF THE MEANS OF COMMUNICATIONS IN RELATION TO EASTERN CANADA OFFSHORE EXPLORATORY DRILLING

Final report

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ASSESSMENT OF THE MEANS OF COMMUNICATIONS IN RELATION TO EASTERN CANADA OFFSHORE EXPLORATORY DRILLING

FINAL REPORT

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SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This study undertaken for the Royal Commission on the "Ocean Ranger" Marine Disaster describes and assesses the means of communications in relation to Eastern Canada offshore drilling. In terms of communications aspects, it is convenient to divide the present activities into three zones based on the distance offshore; coastal (80 km), middle (80 to 350 km), and far (greater than 350 km). As examples, drilling off Sable Island on the Scotian Shelf can be included in the coastal zone while the Hibernia location would be in the middle zone. Two basic types of drilling units are currently in use; fixed, such as jack-ups used in shallow waters, or non-fixed, such as drill ships and semi-submersibles.

A drilling unit needs to maintain long and frequent communications contact with its shore-base. The type of communications services needed and provided on a drilling unit include, voice, telex or teletype, telecopier or facsimile, and data. Both the drilling unit and its shore-base also need to be capable of voice communications with transport helicopter and support vessels. The ship, shore, and helicopter stations are required to meet a fairly comprehensive and detailed set of regulations under Canadian, International and other national conventions.

All the drilling units currently in operation in the study area have satellite communications terminals (mostly linked to INMARSAT), which provide voice, telex, telegraph, and data communication services. Satellite communications facilities are being used even though there are no regulations which make them mandatory. These terminals, through geostationary space satellites, provide a highly reliable link to the shore-base. The satellite terminals are equipped with an emergency override channel which provides immediate and automatic access to shore when activated. However, due to the present satellite user costs, the prime communications among the components of a 'drilling system' are basically provided by MF/HF and/or VHF links.

Of the two links, the VHF link is more reliable but is only effective up to ranges of approximately 80 km. This then is the primary link for line-of-sight distances and is used as such in the coastal exploration zone. The MF/HF links utilize ground and/or sky wave mode of propagation. The ground wave mode is more reliable than the sky wave mode but its effective range is up to approximately 350 km. The ground-wave mode then is prevalent for drilling operations in the middle exploration zone while the sky wave MF/HF mode is relevant to the far zone.

The inherent reliability of the above links may get degraded in practice or operations due to the occurence of severe environmental conditions. Adverse conditions such as lighting, rain or snow, and wind storms as well as the presence of sea ice may affect quality of communications and reduce usable range. As a result of these conditions, a particular communication link may fail, significantly degrading communicatons reliability. The VHF links suffer the least while the MF ground-wave propagation links may be severely affected during wind storms. The HF sky-wave links further suffer from variations in the ionospheric conditions which may introduce significant noise during night and thus degrade communications reliability.

The communications link with the helicopter is primarily provided by the VHF aeronautic band while the prime link with the support vessels is provided through the VHF marine band. Both helicopter and support vessels carry MF/HF equipment as well. These links perhaps are somewhat weaker than those between the drilling unit and the shore-base because they include the satellite link. All the above links have multi-channel capability, thus providing redundancy. The communication equipment used on individual "drilling system" components (drilling unit, shore-base, support vessel, and transport vessel) consists of redundant or back-up equipment. In particular, on drilling units and shore bases, multiple antennas and receivers and spare transmitters are provided, with automatic selection and

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switchover capability. Adequate back-up or emergency power is provided through lead acid batteries.

Although any two components of two nearby networks do not seem to share a common private frequency, they can easily talk to each other through a number of frequencies provided on the VHF, MF, and HF bands for public correspondence. Moreover, calling frequencies (e.g., international distress at 2182 kHz and those assigned to individual coast Guard stations) may be used to establish a common working frequency for temporary use through an intermediatory coast guard station. These stations are required to maintain a continuous listening watch on international distress and calling frequencies (500 kHz - telegraph under SOLAS, 2182 kHz, and 158.6 MHz). Most of the ship stations are also required to maintain this watch.

The offshore communications in the study area at present appears to be adequate to meet the needs of the exploration companies as well as be practically reliable in reasonable terms. This reliability can be enhanced through the following:

i) By clarifying the applicability of Canadian regulations to offshore drilling units (especially those foreign owned) and by clarifying apparently conflicting requirements,

ii) By requiring all transport helicopters to be equipped with VHF marine band radio equipment and/or for all support vessels to carry VHF aeronautic band radio equipment,

iii) By requiring all drilling units operating at distances greater than approximately 80 km offshore (perhaps outside the VHF coverage area of the Coast Guard Station) to be equipped with satellite communication terminals,

iv) By requiring frequent preventative maintenance schedules for communications equipment and by requiring installation of performance monitoring and display devices,

v) By requiring spare communications equipment parts on drilling units and the services of a qualified electronics technician,

vi) By requiring a communications contingency plan,

vii) By encouraging exploration operators to pool resources and thus, provide optimized antenna facilities at the shore for communications to a particular offshore region and,

viii) By compiling communication reliability data base for the study area and encouraging research into improving MF/HF, and VHF communications reliability through improved antenna designs and employment of space, path, frequency, and polarization diversity.

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1.0 INTRODUCTION

1.1 General

This study was commissioned by the Royal Commission on the Ocean Ranger Marine Disaster (RCORMD) to assess the means for communications in relation to the Eastern Canada offshore exploratory drilling. Safe offshore operations require reliable means of communications between various components of a "drilling system"; namely, the drill unit, shore-base(s), support vessel(s), and transport helicopter(s). Fail-safe means are needed for communicating emergency or distress signals between two points and for transmitting and receiving one or more information types - voice, data or text, and video.

A simplified illustration of the various links as the parts of an external communications network associated with a "drilling system" is shown in Figure 1. The communications link between two components or points is provided through propagation of electromagnetic waves or energy. (The information to be conveyed, e.g., voice, is converted into electromagnetic energy, i.e. radio waves, which are transmitted and upon reception converted back into the original form, e.g., voice). The frequencies or frequency-bands in the electromagnetic spectrum (e.g. Medium (MF), High (HF), and Very High Frequencies (VHF), Microwaves, etc.) employed for communicating between two points on the earth's surface are determined by a number of factors which include the existence of a direct or line-of-sight path, the intervening distance, and the environmental conditions. The use of the electromagnetic frequency spectrum is controlled under Canadian and International Regulations.

Two points may be joined directly by a connecting cable, or, for line-of-sight distances, for example, through microwaves or VHF. The communications link for over-the-horizon distances (i.e., beyond the line-of-sight) is primarily provided through MF and HF bands. Two points at a distance apart greater than the line-of-sight may be connected through an intermediate relay station, such as a space satellite, which provides a reliable direct, or line-of-sight, link to

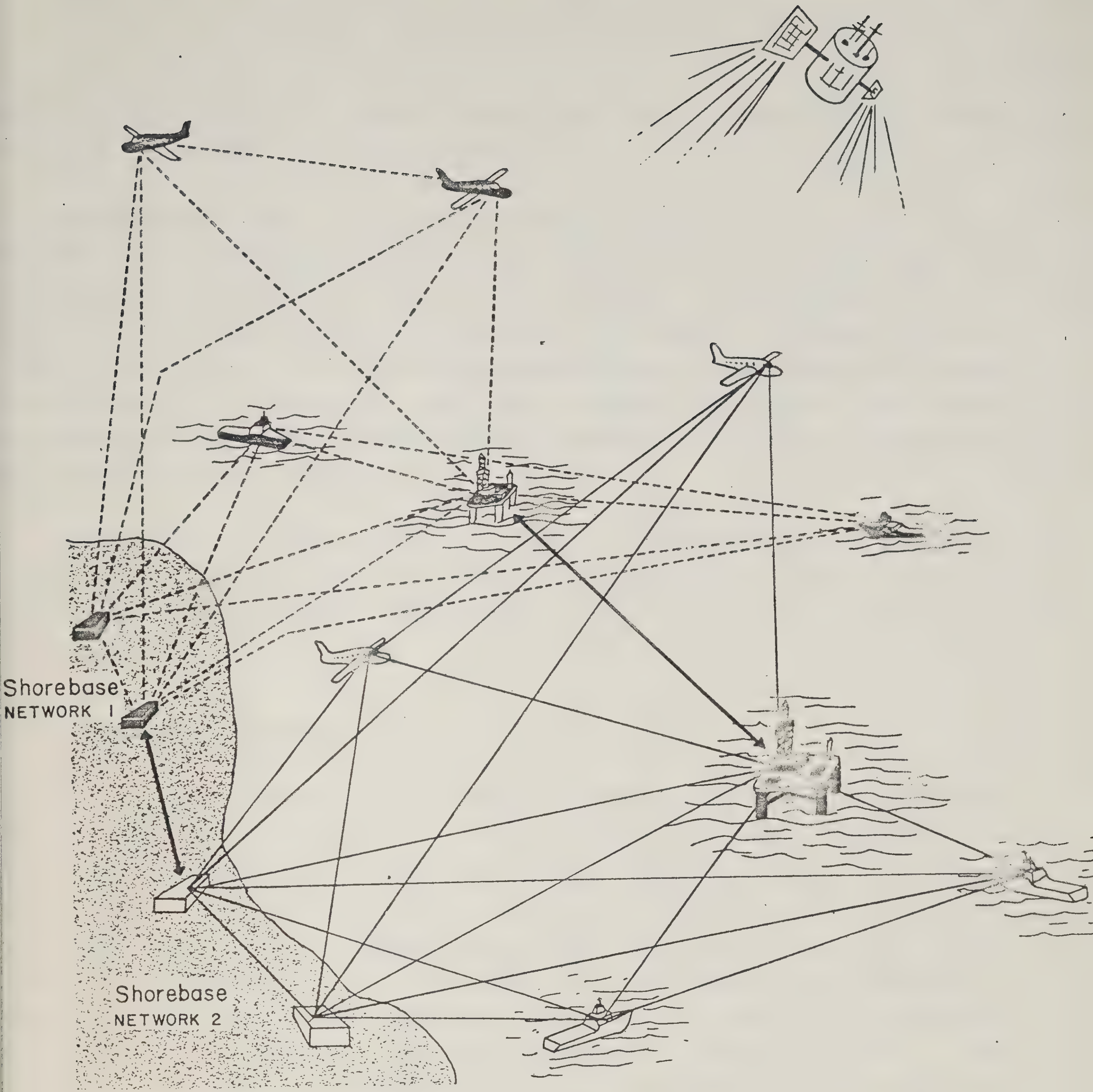


FIGURE 1 : Simplified Representation of Offshore Drilling Communications Networks.

each point. For this reason, satellites are finding an increasing role and importance in communications.

Accordingly, there may be one or more communication links (e.g., VHF,HF, etc.) between two components of a "drilling system" and each link may be operable at more than one channel or frequency. A drill unit, as part of the total communications network, has the external links connected to its internal communications system usually through one primary node (normally the radio operator console). Two nearby networks may be joined through inter-connections of major components, as illustrated in Figure 1.

This report describes and examines the relevant means of communication associated with a "drilling system" in accordance with the terms of reference of the study which are given in Appendix A and outlined below.

1.2 Terms of Reference

The Terms of Reference of the Royal Commission on the Ocean Ranger Marine Disaster call for a broad-ranging study plan, pertaining to offshore drilling and related activities, which includes five areas: environment, regulation, design, safety, and training. The geographic area for these studies (Figure 2) extends from the shore-line to the limit of jurisdictional claims, and from the Canada-U.S. boundary to the northern limit of the area serviced by east coast ports and where marine drilling systems are used (Lancaster Sound at 75°N). The issue, in all studies is human safety, with property safety only to be considered to the extent it affects human safety.

The purpose of the study reported here is to describe and assess the means of communications in relation to eastern Canada offshore exploratory drilling and to provide practical possibilities for improving these means, if so required. The study requirements include provision for the following:

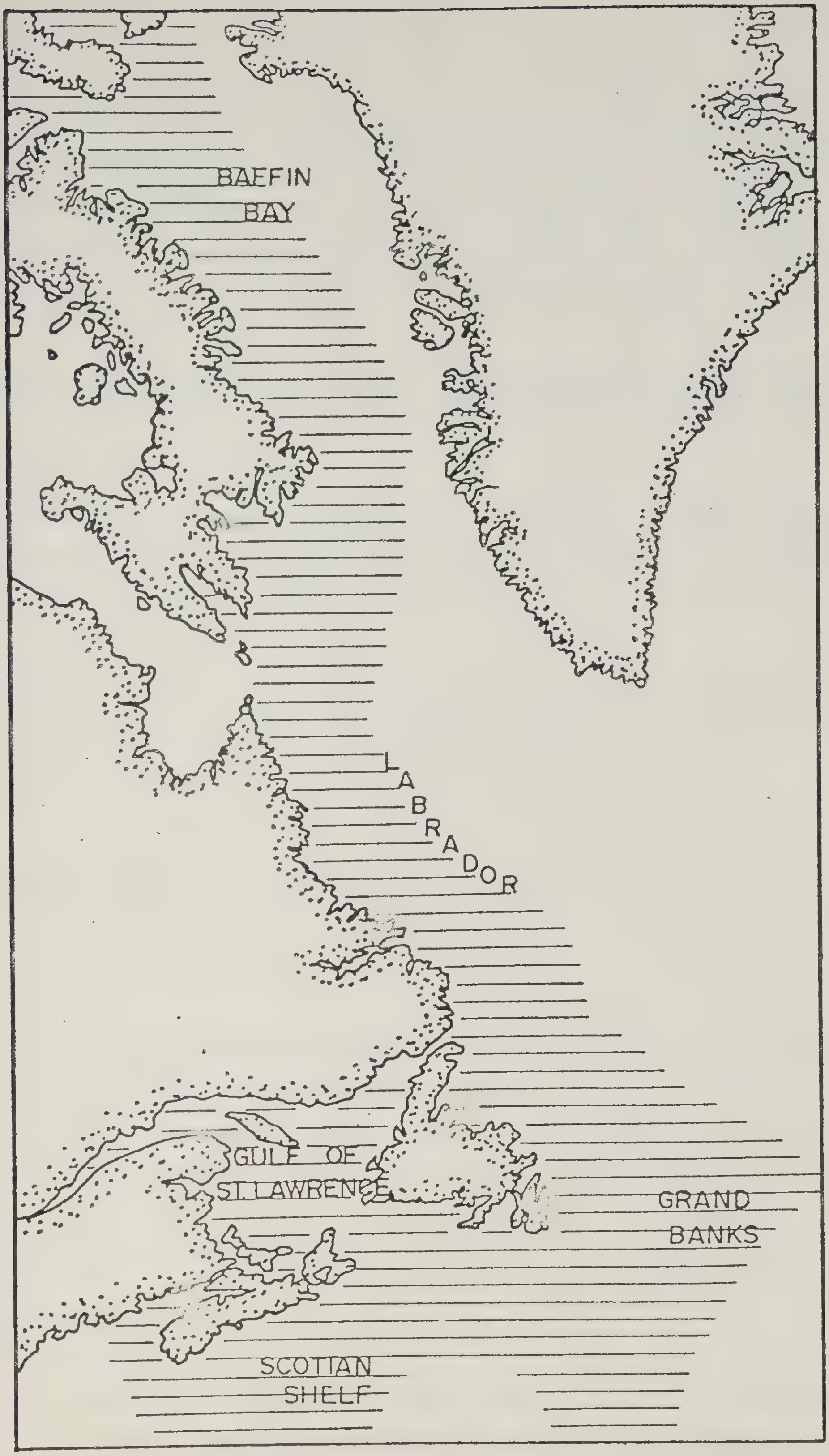


FIGURE 2. Royal Commission on the Ocean Ranger Marine Disaster - East Coast Offshore Study Area

i) To describe individual communications and total communications networks currently in use in the study area (internal communications systems of a drilling unit and external communications systems of each component of a "drilling system");

ii) To evaluate the suitability and adequacy of system described in (i);

iii) To identify and assess conditions resulting in the loss of communication between various components of a "drilling system" in the study area;

iv) To identify inherent redundancy within each communications link and network in terms of maintaining continuous communications between each component;

v) To identify communications systems under development and those currently in use in the drilling industry and other industries in other offshore areas; and,

vi) To identify the "most desirable" communications system (if current systems are found insufficient) for a "drilling system" off the Canadian east coast using combinations of individual systems currently in use or those under development.

1.3 Organization of Study

Background information for the study area, such as geographical and environmental aspects and the current level of drilling activity, is outlined in Section 2. This section also includes a summary of related information for some other offshore areas such as the Arctic and the North Sea. The offshore communications requirements and applicable regulations are discussed in Section 3. The communication systems currently operating in the study area are described in Section 4 while their assessment is undertaken in Section 5. Some of the

pertinent information for these systems was obtained through a questionnaire sent to Canadian Oil Companies and the Canadian Coast Guard. On the basis of these responses, typical systems are discussed. The applicability to the study area of systems operating in other offshore areas and those under development is explored in Section 6.

2.0 STUDY AREA

2.1 Geography and Environment

The area of concern extends some 3000 km from the United States border in the south, to Lancaster Sound at the entrance to the Northwest Passage. The climate varies from temperate to Arctic. The width of the continental shelf to the 200 m isobath varies from 200 km of Nova Scotia to 400 km southeast of Newfoundland. Further North off Labrador the shelf break generally occurs at 300 m and 150 km from the coast. East of Baffin Island, there is virtually no shelf and the sea-bed plunges to a depth of 1000 m within 50 km of the coast.

Exploration permits, reflecting the current knowledge of sedimentary basin structures on the east coast, have been awarded for parts of the Gulf of St. Lawrence, large parts of the Scotian Shelf (particularly near the Shelf break), the eastern and northern Grand Banks, northeast of Newfoundland and along the coast of Labrador (Figure 3). The only permit areas off Baffin Island are at the latitude of Davis Strait and at the entrance to Lancaster Sound. The relevant environmental parameters effecting communications for the five offshore sectors or regions of the study are summarized in Tables 1 to 4 (from Swail and Mortsch,1983).

Such environmental conditions or parameters as wind or waves, precipitation (rain, snow, thunderstorms), or the presence of sea ice may effect the quality of offshore communications and sometimes may even result in the break down of a communication link (see Sections 4 and 5). Electromagnetic waves are absorbed or attenuated by atmospheric water or moisture (precipitation - rain, snow, freezing rain, etc.), which results in the reduction of an effective communication range or distance. Similarly, the presence of significant ocean waves and, in particular, sea ice may reduce the usable range due to the attenuation of ground waves (radio waves,using the ground mode for propagation, i.e., propagating along the surface of the earth).

FIGURE 3. Oil and Gas Exploration Lease Areas

AREA	Mean Wind kt		Gale Wind ($\geq$ 34kt)	Severe Storm Yearly Average (Sustained Winds kt)	Remarks
	Min. (Month)	Max. (Month)	%time (mth)/persistence in days		
Sable Scotian Gulf	11 (July)	21 (Jan)	10 (Jan)/ 2 - 3	Once (70)	Hurricanes - anytime from May to Nov. more likely between Aug. and Oct.
Gulf of St. Lawrence	12 (July)	21 (Dec. to Feb.)	12 (Dec. to Feb) / 2-3	Once (70)	Hurricanes, occasional, but with reduced winds, local coastal effects important.
Grand Banks	11 (July)	21 (Dec. to Jan)	12-13 (Dec & Jan) / several	Once (75)	Hurricanes occasional
Labrador Sea	12-13 (June to April)	19 (Nov. to Jan.)	11 (Dec to Feb.) /Several	Once (65-75)	Mean winds for Eastern portion. 24kt from Nov. to Feb.
Davis Strait/ Baffin Bay	12/7-9 (June to Aug.)	19/16 (Dec. to Feb.)	6-8 (Dec. to Feb) -West Davis 3 (Jan) -Baffin	Once (60/50)	Local coastal effects important.

Legend: $\geq$ (Greater than or equal to)
% (Percentage)
kt (knots)

TABLE 1: Extreme Wind Speed Summaries for East Coast Offshore Areas (Adapted from Swail and Mortsch, 1983)

AREA	Highest Month % Heavy Rain	Month Occur	Highest Month % Thunderstorms	Month Occur
Sable Scotian Shelf	3	May - Aug.	0.6	July
Gulf of St. Lawrence	3	Oct. - Nov.	1.0	July - Sept.
Northern Grand Banks	4	Sept.-Nov.	0.3	July
South Labrador Sea	3	May	0.2	July - Aug.
Davis Strait	1	July	0.1	Several

TABLE 2: Frequency of Heavy Rain and Thunderstorms for East Coast Offshore Areas (from Swail and Mortsch,1983

AREA	Maximum % Time Freezing Precipitation	Months (Occurrence)	Months with Freezing Precipitation
Sable Scotian Shelf	0.5	(Feb. - Mar.)	Jan. - April
Gulf of St. Lawrence	1.7	(March)	Nov. - May
Northern Grand Banks	0.4	(Jan.- April)	Dec. - April
South Labrador Sea	1.0	(February)	Nov. - May
Davis Strait	0.8	(October)	All

Legend: % (Percentage)

TABLE 3: Freezing Precipitation Summary for East Coast Offshore Areas (From Swail and Mortsch,1983)

AREA	Maximum % Ceiling ($<$ 300 ft) or Visibility ($<$0.6mi)	Month Occur	Month with $>$ 10% Frequency of Ceiling ($<$ 300 ft) or Visibility ($<$0.6 mi)
Sable Scotian Shelf	36	July	All
Gulf of St. Lawrence	30	July, August	All except February
Northern Grand Banks	45	July	All
South Labrador Sea	21	June	All except April, September
Davis Strait	10	May	May

Legend: % (Percentage)
$<$ (Less than)
$>$ (Greater than)

TABLE 4: Flying Weather Statistics for East Coast Offshore Areas (from Swail and Mortsch, 1983)

A summary of extreme wind conditions for the study area as shown in Table 1 indicates only a slight difference among the five offshore regions or sectors of interest. The minimum and maximum mean monthly wind speeds appear to be about 7 to 10 kt and 21 kt (10.8 m/s), respectively, with gale force winds (greater than or equal to 34 kt) prevailing around 10 percent of the time during the extreme months. Severe storms (winds 65 to 75 kt) seem to average once a year in each of the five representative east coast areas with slightly different frequencies of thunder storms and heavy rain (Table 2). The probability of freezing precipitation (Table 3) tends to decrease with distance from land. Offshore, most freezing precipitation is associated with frontal activity and may last for a number of hours (3 to 24 hours) in an extreme month. In contrast, the combination of low cloud ceilings and low visibilities, which are of interest to aircraft operations appear to be very frequent (Table 4). Ceilings less than 300 ft or visibilities less than 0.5 mile (0.8 km) can seriously curtail aircraft operations and thus increase the importance of proper communications.

As noted earlier, in addition to atmospheric and oceanographic parameters, the presence of sea ice influences the effective range of offshore communications and communications quality. The advance of sea ice in the study area from September to March is depicted in Figure 4. The ice starts to retreat in April and by May the Gulf of St. Lawrence and the Northern Grand Banks are normally clear. The Labrador Coast normally clears of ice during June and July, while at the same time, open waters in northern Baffin Bay start to expand southward. Sea ice normally reaches its minimum extent by mid-September. The variations in the maximum annual extent of the ice cover indicates that while the Grand Banks is ice free during a normal winter, it can be totally ice covered during a severe ice year (Figure 5). Although ice has come close to Sable Island (within 40 km) on several occasions, the island remains outside the extreme limits of sea ice.

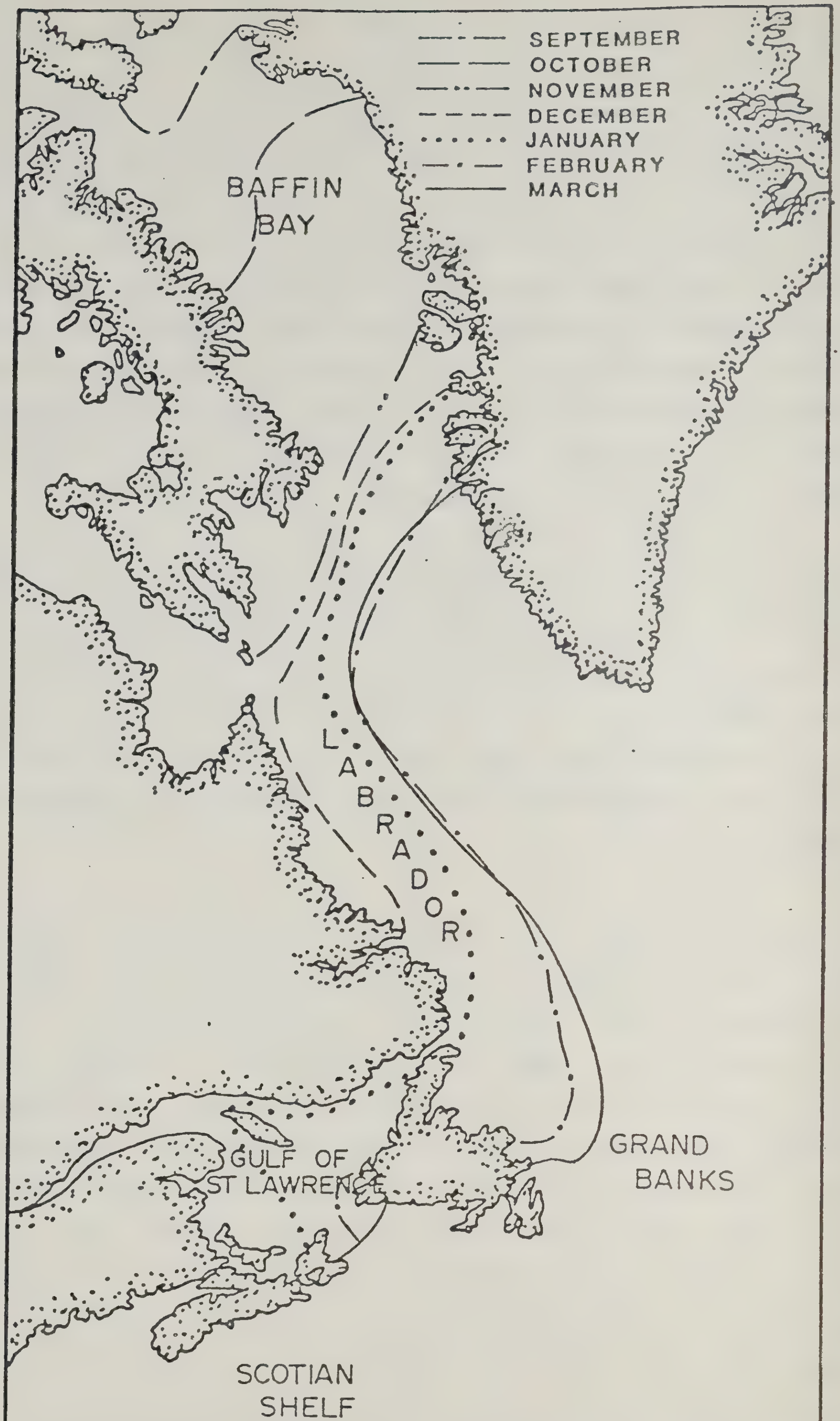


FIGURE 4. Advance of sea ice from September to March

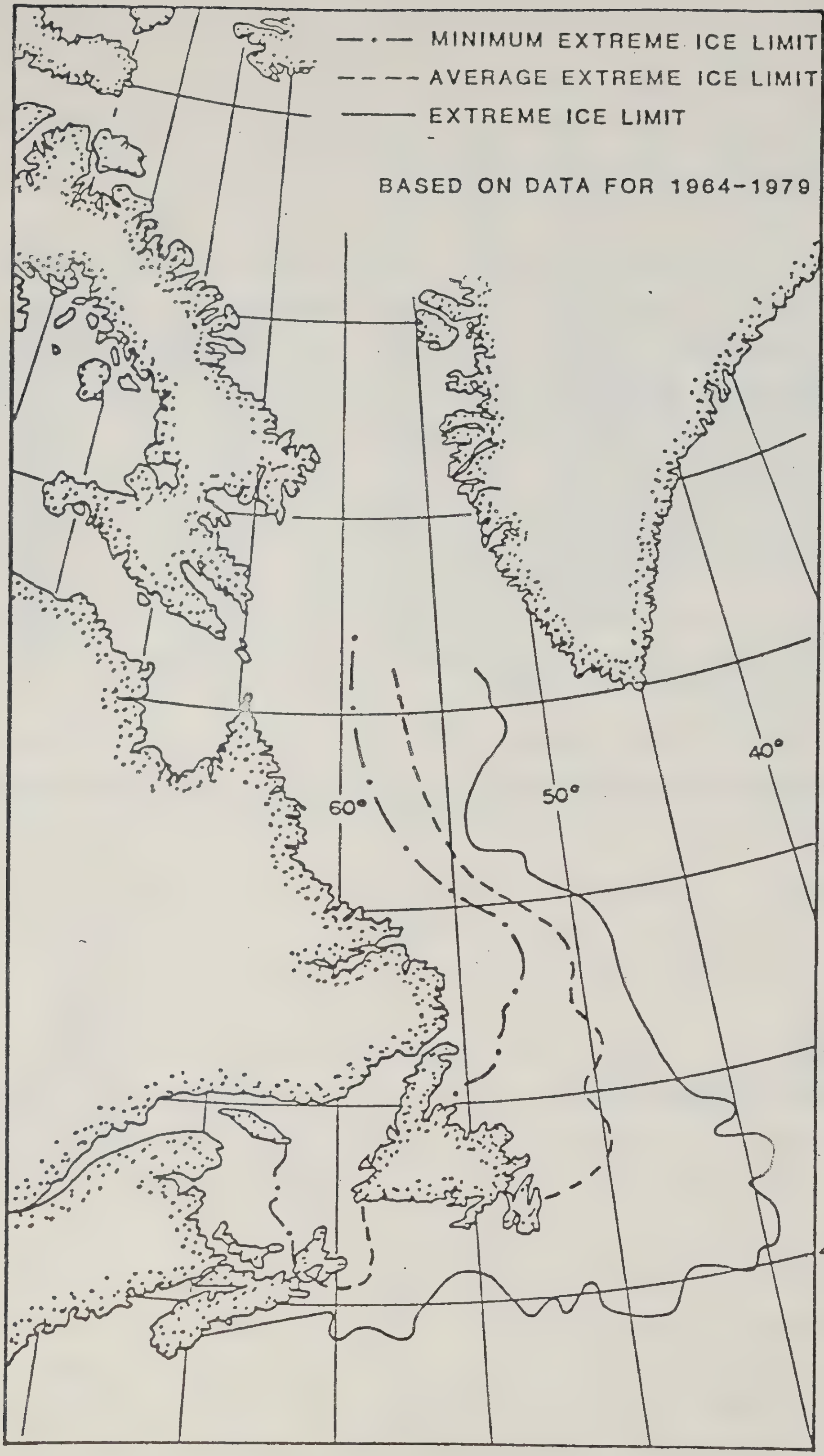


FIGURE 5. Extreme sea ice limits

2.2 Exploration Activity

To date offshore drilling in the study area has been rstricted to the open water conditions, and the type of rig employed (Figure 6) has been dictated by the water depth, wave conditions, and the need for mobility in the path of icebergs or pack ice. Year round drilling has only been possible off Nova Scotia and, with due attention to icebergs and occasional incursion of sea ice, on the Grand Banks. Jack-up systems have been used in the Gulf of St. Lawrence and in the shallow waters close to Sable Island off Nova Scotia. Elsewhere off Nova Scotia and on the Grand Banks off Newfoundland, anchored semi-submersibles have been used.

Off Labrador and in the Davis Strait, drilling has been restricted to the summer months. But dynamically positioned vessels, generally drill-ships, have been used to meet the need for mobility in the path of icebergs. Supply boats (Figure 6) are used on a frequent schedule between a drill unit and a shore base. At least one supply boat is required to stand by a drill unit at all times.

These drill units and vessels used offshore provide motion or orientation stability to varying degrees and offer different heights for mounting communication antennas. A comparision of expected motions (theoretical) that are likely to be encountered by fixed offshore structures is given in Table 5. The practical values may be significantly less and the heave component may be as much as 7m (OST,1981).

During 1983, seventeen drill units were operational in the study area. Among these, four drill ships operated on the Labrador Shelf; four jack-ups operated of Prince Edward Island, New Brunswick, and Nova Scotia; and nine semi-submersibles drilled off Nova Scotia and Newfoundland. A similar level of exploration activity is expected to continue during 1984 and 1985 in the study area.

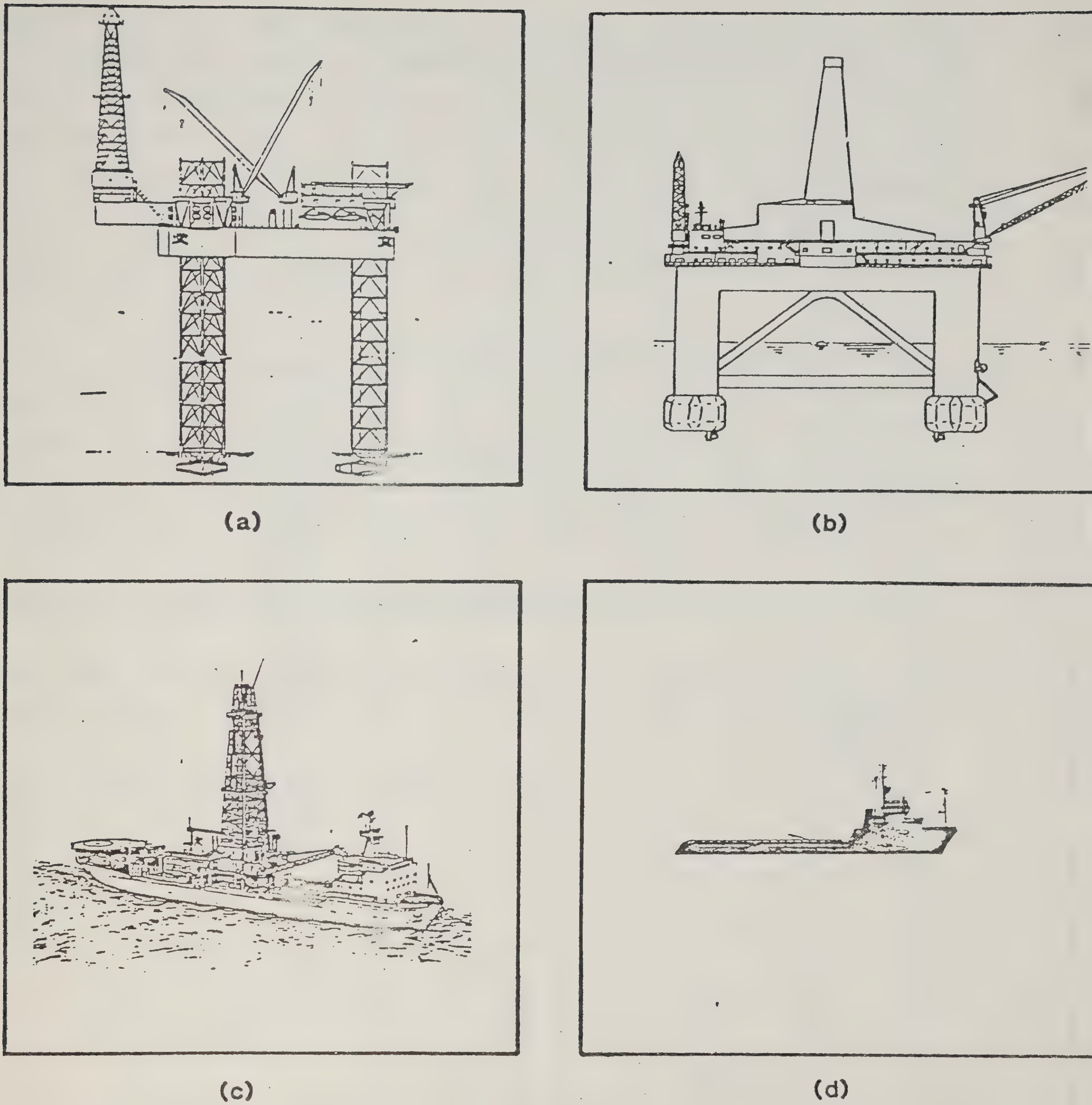


FIGURE 6. Typical drilling platforms and vessels in use off Eastern Canada. (a) Jack-up, (b) semi-submersible, (c) drillship, and (d) supply vessel.

Type	Max Roll (Degree)	Pitch (Degree)	Yaw (Degree)
Semisubmersibles (e.g. 3, 4, and 5 footings; Twin Hull)	10 - 15	10 - 14	1.5 - 3
Drillship	37	23	8
Tension Leg Platforms	0	0	6
Buoy	30	30	5

Table 5. Example of Expected Theoretical Motions (30m wave conditions assumed) For Non-fixed Offshore Structures (From OTS, 1981)

Table 6 provides the approximate distances involved in the current offshore exploration drilling from some typical shore stations. For these drilling operations, communications are primarily required up to distances of 1000 km from the base stations located in St. John's and Halifax, although the vast majority of operations are within 500 km of the base station. However, greater distances (1500 km and more) are involved for communications from St. John's and Halifax to activities off Labrador and further north.

Past exploration activity, as indicated by the lease acreage holdings, has shown that more than one operator (oil company or consortium) may be involved in drilling at two near-by locations (e.g. within 50 km) at one time. Also, two drill units may operate simultaneously at distances of just several kilometres apart.

2.3 Comparison With Other Exploration Areas

Among the other areas where exploration is currently taking place are the following:

- Western Arctic (e.g. Beaufort Sea)

- North Sea

- U.S. West Coast (e.g. off Alaska)

- Gulf of Mexico

As a way of illustrating the differences, Table 7 compares some relevant environmental statistics among the Grand Banks, North Sea, and Beaufort Sea regions. The month of February corresponds to the winter conditions and the month of July to the summer conditions.

Area	Typical Shore Stations	Distance/Range (km)
Scotia Shelf	Primary - Halifax Secondary - Sable Island	200-500 0-500
Gulf of St. Lawrence	Saint John, New Brunswick Prince Edward Island	200-400 0-200
Grand Banks	St. John's, Newfoundland Halifax, Nova Scotia	300-500 1300-1500
Labrador Shelf	Hopedale, Labrador Halifax, Nova Scotia St. John's, Newfoundland	100-500 1200-1600 100-1500
Baffin Bay/ Davis Strait	St. John's, Newfoundland Halifax, Nova Scotia	 1500-3000

Table 6 : Approximate Distances Between Offshore Exploration Areas and Some Typical Shore Stations

Parameter	February		July		
	Grand Banks	North Sea	Grand Banks	North Sea	Beaufort Sea
% Frequency Gale Force Winds ($\geq$ 34 kt)	15	10	< 1	< 1	< 1
Air Temperature (^{o}C)	-1	5	11	13	4
% Frequency Fall Précipitation	33	24	10	15	16
% Frequency of Snow from all Precipitation	60	20	0	0	10
% Frequency of Visibility Less than 4 km	10	5	50	10	25
% Waves Greater Than or Equal to 3.5m	30	25	< 5	< 5	0

Table 7 Comparisons of Environmental Statistics for Grand Banks, North Sea, and Beaufort Sea (from Meserve, 1974; USDI, 1977; NORDCO, 1984)

As drilling in the Beaufort Sea only takes place during the summer months, only the July data are presented for it. In general, the Grand Banks environment appears to be the most severe. But in the Beaufort Sea, sea ice is present even during the summer months.

The main difference between the study area and the Western Canadian Arctic is that most, if not all, of the exploration taking place in the far north at present is in close proximity to land masses (within 100km), whereas generally larger distances (approximately 500 km or less) are involved in the study area. The offshore distances of concern in the North Sea (100 to 400 km) are comparable to those in the study area. However, at present there are two basic differences between operations in the North Sea and the study area. These are as follows:

i) exploration and production activities in the North Sea are occuring within the immediate vicinity of each other; and,

ii) the density of offshore activity in the North Sea is such that line-of-sight direct communications between units (drill or production) is possible.

In addition, North Sea systems operate in relatively shallow water and do not have to contend with ice, allowing the use of fixed platforms.

In comparison with exploration platforms, the production platforms require more of a permanent communication link. The production platforms may be fixed or non-fixed, but in either case, are designed on a "fixed for life" or site-specific concept. Due to their fixed nature and long term use, costly and integrated communication facilities or installations are cost effective on the production systems.

The exploration activities off the American west coast and in the Gulf of Mexico are also being undertaken near the shore (within 100km). Up to four hundred jack-up rigs are operating in the Gulf of Mexico, indicating the significant density of offshore activity. Approximately half of these rigs are involved in a production phase.

3.0 COMMUNICATIONS NEEDS AND REGULATIONS

3.1 Study Area Needs

As noted earlier, the basic need during offshore exploration is the capability for communications between;

i) drilling unit and shore base,
ii) drilling unit and support vessel(s),
iii) drilling unit and helicopter,
iv) shore base and support vessels, and
v) shore base and helicopter.

Each of the above needed communications links, except possibly for (i), involves a variable distance or range. The distance between the drilling unit and the shore base remains fixed for a long period of time (up to several months) coinciding with the exploration activity taking place at one location. However, at certain times a drill unit may have to move from its drilling location to avoid an approaching sea ice pack or iceberg.

These communications links may require provision for the following services;

i) transmission/reception of voice-telephone throughout most of the day,
ii) transmission/reception of printed page (text or drawing) - telecopier or facsimile for several hours per day,
iii) transmission/reception of text (alphanumeric characters) - teletype or telex for few hours per day, and
iv) transmission/reception of data (e.g., air and sea temperatures).

A drilling unit, being the main or central component of a "Drilling System", requires regular and possible lengthy contact with its controlling office (i.e., shore base). Due to the critical

and costly nature of oil/gas drilling, immediacy of access to the base is essential. Also, due to the sensitive nature of the drilling information or results, high confidentiality in communications circuits or links is usually required. Practically all the services listed above are needed on a drilling unit to allow communications with a shore base.

Voice is the primary mode of communications between a drill unit and a shore base as well as between other components. Facsimile and teletype are needed to transmit written information such as the daily drilling and progress reports to a shore station. Thus, there is a requirement for quality long distance telephone and fascimile communications. A reliability greater than 95 percent has been stated to be adequate in meeting communications needs of an oil company (Petrie and Campbell, 1974). However, a need for reliability of as much as 99.8% has been quoted for the North Sea operations (Hill, 1980). The data transmission need is obviously dependent on the operations and procedures of each company.

A drilling unit also needs to maintain voice communications with support vessels and transport helicopters. Voice communications capability is also needed between a shore base and support vessels and helicopters. It is a usual practice for a helicopter to maintain a twice weekly schedule, while support or supply vessels may also follow a 2 day cycle, between a drill unit and a base.

In addition to meeting the business needs as well as the social needs of their staff, offshore drill units and support vessels must be capable of communicating emergency or distress signals. These and other requirements follow from the Canadian and international regulations.

3.2 Study Area Regulations

The relevent regulations (Figure 7) are basically concerned with the assignment of electromagnetic frequencies, the type of installation (equipment) required and associated issues. The frequency

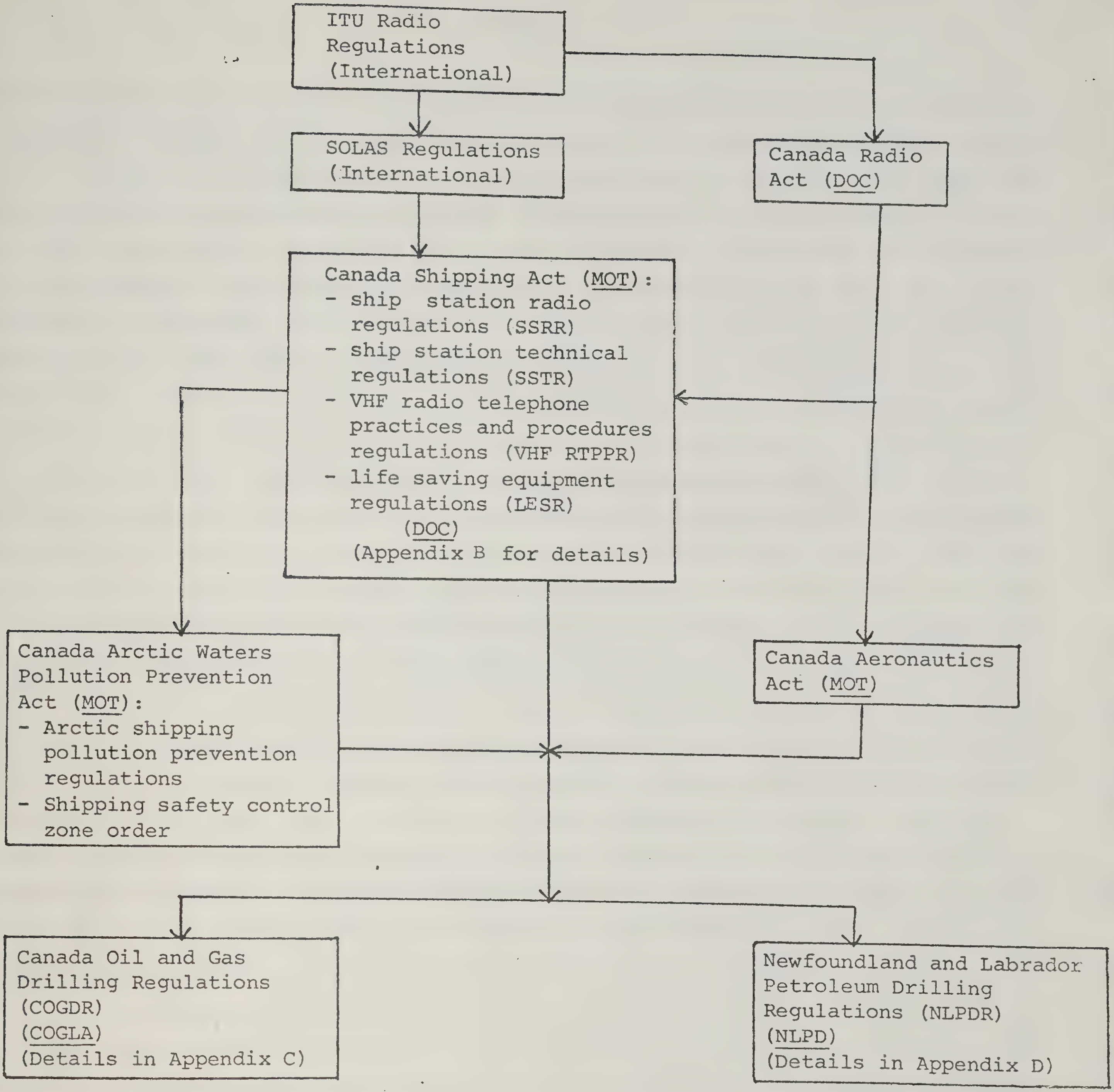


Figure 7: Relevant Regulations for the Study Area (Canadian and Provincial Departments or Ministries Administering Regulations are Underlined)

allocations and related aspects (e.g., technical standards) for various communications and other radio services on a world-wide basis arecontrolled by the International Telecommunications Union (ITU) under an international treaty (ITU, 1959). Similarly, ships registered in countries which are party to the International Convention for the Safety of Life at Sea (SOLAS), must comply with a set of regulations governing radio installations and communications procedures (SOLAS, 1974). To date more than seventy countries are signatories to the SOLAS convention including Canada.

The ITU frequency allocations are further sub-divided by regulations of individual countries for use among particular types of services within the national boundaries. Canada has these (e.g. Radio Act) and other regulations including those governing installations and procedures pertaining to maritime mobile communications (communications between a coast station and a ship or between ships). These regulations (Appendix B, C, and D) are fairly detailed and comprehensive but there appears to be some minor conflict among certain regulations and some aspects need clarification.

It is unclear as to what classification a drilling platform comes under in current national and international maritime regulations now in effect. These regulations are basically defined in terms of ship type (cargo, passenger, etc.). It has been a common practice to date to treat a drilling platform as a cargo ship. But in order to clarify the situation the Canadian Coast Guard (CCG) is in the process of preparing standards for Mobile Offshore Drilling Units (MODU's). A set of proposed interim standards has been prepared (Hornsby, 1983).

More importantly, there is some question regarding the applicability of Canadian regulations to offshore drilling platforms (especially semi-submersibles, jack-ups, and artificial islands) which are not registered in Canada and operate outside of 12 mile coastal limit (territorial waters) even though within the 200 mile economic zone (EPOA/APOA, 1983 and RCORMD Hearings, Wilcox, 1982). The legal or jurisdictional aspects of relevant regulations are beyond the scope of this report. A description of these regulations is provided below

without regard to their strict legal applicability to offshore operations in the study area. In any event, the communications needs of the offshore operators (oil companies) seem to generally outweigh the requirements set forth in these regulations.

The general relationship among the relevant regulations is shown in Figure 7. The key regulations are SOLAS and those under the Canada Shipping Act. The Canada Shipping Act regulations include those of SOLAS. The remaining Canadian regulations (including provincial, such as those of the Government of Newfoundland and Labrador - NRPDR, which is administered by the Newfoundland and Labrador Petroleum Directorate (NLPD)) basically add on to these regulations or make them more specific.

The basic SOLAS regulations (applicable to signatory countries) are summarized in Table 8. Normally in order to inspect a foreign SOLAS convention ship, a request must first be received from the country of registry. This was the procedure followed for the "Ocean Ranger". Under special circumstances ships can be exempted from these regulations as was done with the "Ocean Ranger" (RCORMD Hearings, Wilcox, 1982). Ships registered in countries, which are not parties to SOLAS when inspected are not issued safety Radio Certificates as per normal practice but are inspected to the Canada Shipping Act (CSA) and SOLAS regulations for customs clearance purposes only.

The Canadian Shipping Act (CSA) and the Arctic Waters Pollution Prevention Act Regulations apply to all ships operating in Canadian waters. These regulations are much more stringent than those provided under the SOLAS convention. The Ship Station Radio Regulations (SSRR) set further communication equipment requirements for ships. They require that the installation and equipment meet at least the standards set forth in the Ship Station Technical Regulations (SSTR) and the standards for Radio Installations and Related Equipment (CCG, 1982). Anyone wishing to operate a radio station in Canada must apply for and acquire a valid license (Dept. of Communications, RSP 101, 1972). Both coast and ship station transmitters and receivers must meet strict Canadian standards (Dept. of Communications, RSS 181, 1970).

INSTALLATION	RANGE (NMI)	FREQUENCY	RECEIVER SENSITIVITY (MICROVOLTS)	ANTENNA	EMERGENCY EQUIPMENT
Radio-Telegraphy (reserve system required)	150 (>1600 tons) 100 (<1600 tons)	TX 500 KHZ - 2 working frequencies between 405 and 535 KHZ - emissions determined by ITC-RR* RX 500 KHZ - frequencies used for time signals, meteorological information other frequencies related to safety of navigation - emissions determined by ITC-RR	50	Main antenna plus spare	- Radio Telegraph Auto Alarm (unless 24 hour watch maintained) - Radio Telephone Distress Watch Receiver
Radiotelephone Installation (For cargo vessels ≤ 1600 tons) and not fitted with radio-telegraphy equipment	150 (≥ 500 tons) 75 (≥ 300 tons, for new Installations 15 watts required, no range given)	TX - 2182 KHZ - at least 1 other frequency between 1605 and 2850 KHZ - emission designated by ITC-RR RX - 2182 KHZ - 1 other frequency between 1605 and 2182 KHZ - meteorological information - any other related to safety of navigation - using emissions designated by ITC-RR	50	"	- Automatic Radiotelephone Alarm Signal - Radio Telephone Distress Watch Receiver

TABLE 8

A SUMMARY OF MAIN COMMUNICATIONS EQUIPMENT REQUIREMENTS NECESSARY UNDER SOLAS FOR RADIO INSTALLATIONS ON CARGO VESSELS

*ITC-RR - International Telecommunications Convention Radio Regulations

NOTES:

1) These regulations apply to cargo vessels over 300 tons gross tonnage.

2) All installations require sufficient reserve power to operate normally for six hours.

3) One portable lifeboat radio apparatus is required on each vessel.

4) The equipment standards are governed by the most recent International Telecommunication Convention (ITC), which also provides the Radio Regulations (RR).

5) Canada has utilized the equivalency clause of the SOLAS convention to allow under certain conditions the fitting of a SATCOM installation in lieu of a radiotelegraph installation when making international voyages.

The specific equipment requirement based on the CSA are, in part, determined by which of the three frequency zones (Figure 8) the ship is operating in: VHF, MF, HF, or International (outside HF coverage). The basic radio equipment requirements for a ship in each of the areas is summarized below (CCG, NR, 1981, also see Appendix C for details):

VHF	MF	HF	International
2-VHF radio-telephones or 1-VHF and 1-MF radio-telephone	1-VHF and 1-MF radio-telephone	1-VHF and 1-MF radiotelephone & either 1-MF/HF radiotelephone or 1-MF radiotelegraph	1-VHF and 1-MF radiotelephone & 1-MF radio-telegraph

Under the SOLAS convention in any of these areas the drilling rig would only be required to have a MF radiotelegraph system (which, incidentally transmits and receives Morse code only). For supply vessels which are usually less than 1600 gross tons the only difference in the Canadian equipment requirements regulations from the preceding is that in ocean areas beyond HF areas they must carry 1 VHF and 1 MF radiotelephone, and 1 MF/HF Radiotelephone or 1 MF radiotelegraph. Under the SOLAS convention these ships would only require 1 HF radiotelephone or 1 MF radiotelegraph.

Some details of the equipment requirement per the SSTR are provided in Table 9. These include the emission type and levels. To improve the efficiency of maritime commincations, only single sideband emissions made in MF and HF bands is permissible (Dept. of Communications, TRC-11, 1977; TRC-14, RSS 181). Under the SSTR, radio watches must be maintained on a continuous basis. Also under the SSTR each MF radiotelegraph installation must be operated by an operator holding at least a Second Class Radiotelegraph Operator's Certificate, and MF, MF/HF and VHF radiotelephone installations must be operated by a person holding the same or at least a Restricted Radiotelephone Operator's Certificate. These certificates, of course, are those issued by the Canadian Government under the Radio Act.

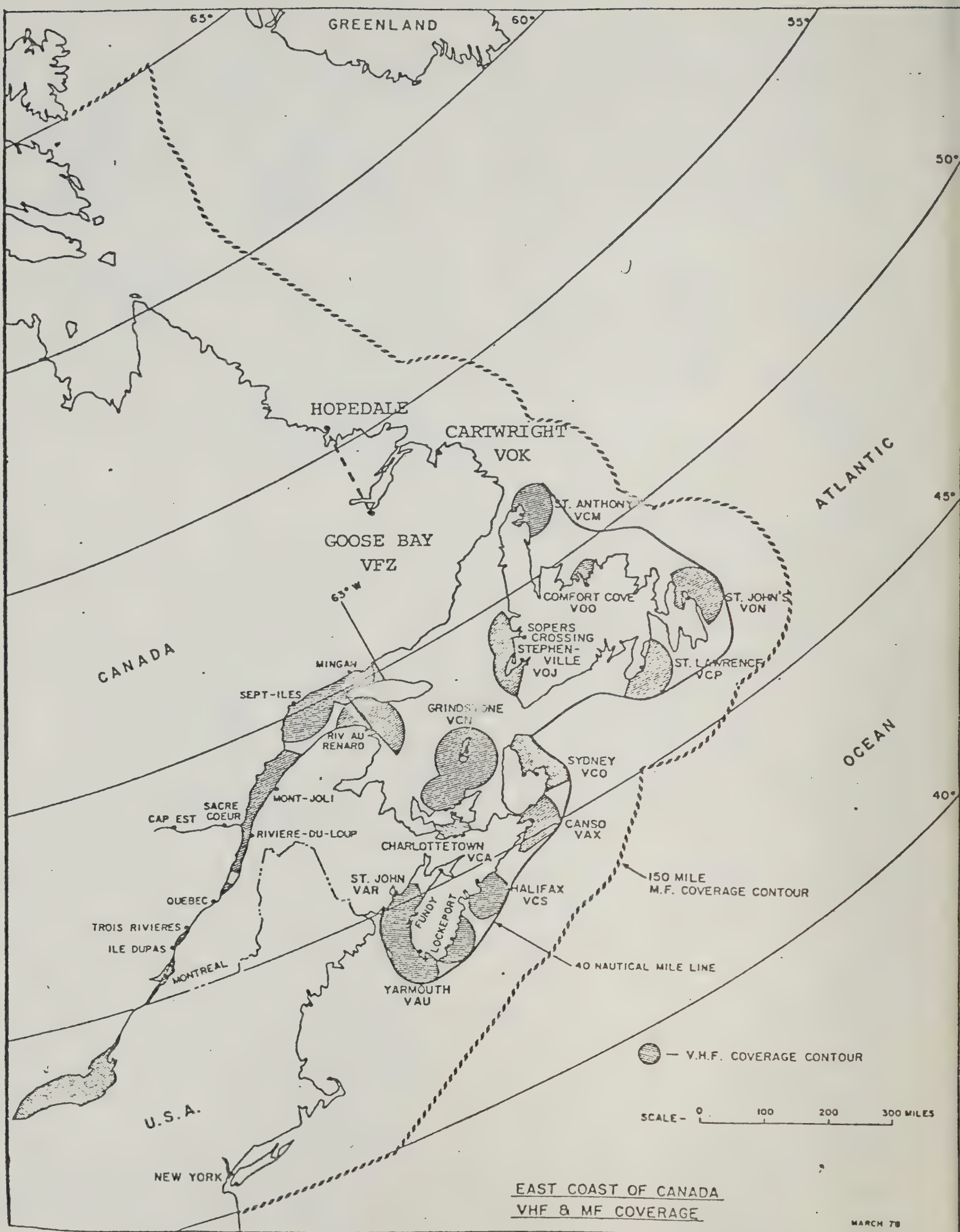


FIGURE 8 Coast Guard Radio Station Coverage Zones for East Coast of Canada (From CCG, NR; 1981)

INSTALLATION	RANGE (NMI)	FREQUENCY AND EMISSION TYPE	TRANSMITTER POWER (WATTS)	RECEIVER SENSITIVITY (MICROVOLTS)	ANTENNA	ALARMS
MF Telegraphy (reserve system required)	150 (>1600 tons) 100 (<1600 tons)	TX -410 KHZ-A1,A2 or A2H -500 KHZ-A2 and A2H -any two of 425 KHZ-A1,and A2 or A2H 454 KHZ- " 468 KHZ- " 480 KHZ " 512 KHZ " RX -405 to 535 KHZ- A1 and A2 or A2H	NP*	25	-designed and installed to provide maximum practical efficiency	- Alarm signal keying device -receive auto alarm
MF Radiotelephone	150	TX -2182 KHZ -one inter-ship. channel appropriate to area -one ship-to-shore public correspondence channel appropriate to area of operation -A3H and A3A or A3J RX A3, A3H and A3A or A3J -frequencies as above and for meteorological and safety of navigation data	25	1.5 (A3 or A3J 3 (A3 and A3H)	" -as high as practically possible -ships $\geq$ 20 metres require one spare for 2182 KHZ	-Alarm signal devise -Radio-telephone distress frequency watch receiver

TABLE 9

A SUMMARY OF THE MAIN EQUIPMENT REQUIREMENTS NECESSARY UNDER CSA SSTR RADIO INSTALLATIONS ON CARGO SHIPS

*NP - Not Provided

Explanation of Emission Codes

Telegraphy	A1	Telegraphy without the use of modulating audio frequency.
	A2	Telegraphy using amplitude modulation of an audio frequency.
	A2H	Modulated tone using a full carrier (used for emergency beacon)
Telephony	A3	Double sideband, full carrier.
	A3A	Single sideband reduced carrier.
	A3H	Single sideband full carrier.
	A3J	Single sideband suppressed carrier.
	F3	Frequency modulation.

TABLE 9 (Cont'd)

INSTALLATION	RANGE (NMI)	FREQUENCY AND EMISSION TYPE	TRANSMITTER POWER (WATTS)	RECEIVER SENSITIVITY (MICROVOLTS)	ANTENNA	ALARMS
MF/HF Radiotelephone	150	Same as MF telegraphy installation plus -A3A or A3J on at least one two frequency duplex ship-to-shore channel in each of the 4,6 and 8 MHZ Maritime Mobile Bands as appropriate to the area -A3H at 2182 KHZ	- 35 - 25 if system installed before Jan. 1/80	NP	NP	"
VHF Radiotelephone	NP	F3 -156.8 MHZ -156.3 MHZ -one public correspondence frequency appropriate to area -such other VHF channel as required for safety purposes and appropriate to area -frequencies which provide navigation warnings	- 15 to 25 (must be reducible to one watt) -10 on installations before Jan. 1/80	2	vertically polarized as high as possible	NP

NOTES:

1) These regulations only apply to Canadian Registered Cargo Vessels or Foreign Registered Cargo Vessels licensed to routinely operate in Canadian territorial waters. Also current practice is to class offshore drilling platforms as cargo vessels.

2) All installations require sufficient reserve power to operate normally for six hours.

3) Above 65°N all ships must carry a spare antenna completely assembled and capable of quickly replacing its main antenna.

4) Type A or Arctic Class Ships north of 65°N latitude and in a shipping safety control zone must have equipment capable of receiving fixed images transmitted from a Canadian radio station and an ice reconnaissance aircraft.

5) One portable lifeboat radio apparatus is required on each vessel.

6) The Canadian Government under the equivalency clause of the CSA will allow certain cargo vessels to be fitted with a SATCOM installation in lieu of a radiotelegraph installation.

Under the Aeronautics Act, a helicopter (a prime mode of transport between offshore platforms and shorebases) must be able to maintain two way communications (voice) with a control centre througout its flight. The type of equipment is not specified. The helicopter is also required to carry an emergency locator transmitter and, under instrument flying rules, radio direction finding equipment. Under the LSER a portable radio apparatus (radiotelephone) is to be carried on a ship for use in a lifeboat (but not necessarily stowed in a life boat). The SSTR states that this is to be a MF/HF radiotelephone or an MF radiotelephone (to operate at 2182 KHz).

The Arctic Waters Pollution Prevention Act requires under the SSRR that a Type A or Arctic Class Ship (as per the ASPPR) which is north of 65 parallel of North Latitude and in a shipping safety control zone (see Figure 9) must be equipped to receive fixed images transmitted from a Canadian radio station and an ice reconnaissance aircraft.

Foreign ships are only required to comply with Canadian regulations if they routinely operate in Canadian waters (for which they require a special license). Those which only enter Canadian waters very rarely are only inspected for compliance with SOLAS convention regulations and only then when Canada is requested to do so by the country of registry or before it departs a Canadian port. The DOC carries out all inspections on behalf of Ministry of Transport (via the CCG). Canadian registered ships must comply with the regulations in national and international waters. (Transport Canada, TP-1896, 1981).

Canada has applied the equivalency clause in the SOLAS convention to allow certain Canadian cargo ships to use satellite communications (SATCOM) installation in place of the radiotelegraph installations normally required by SOLAS (CCG, 1982). This applies to cargo ships normally engaged in coastal voyages but making occassional international voyages. These ships would not require radio officers but must have two deck officers who have been instructed in the proper use of the SATCOM installations.

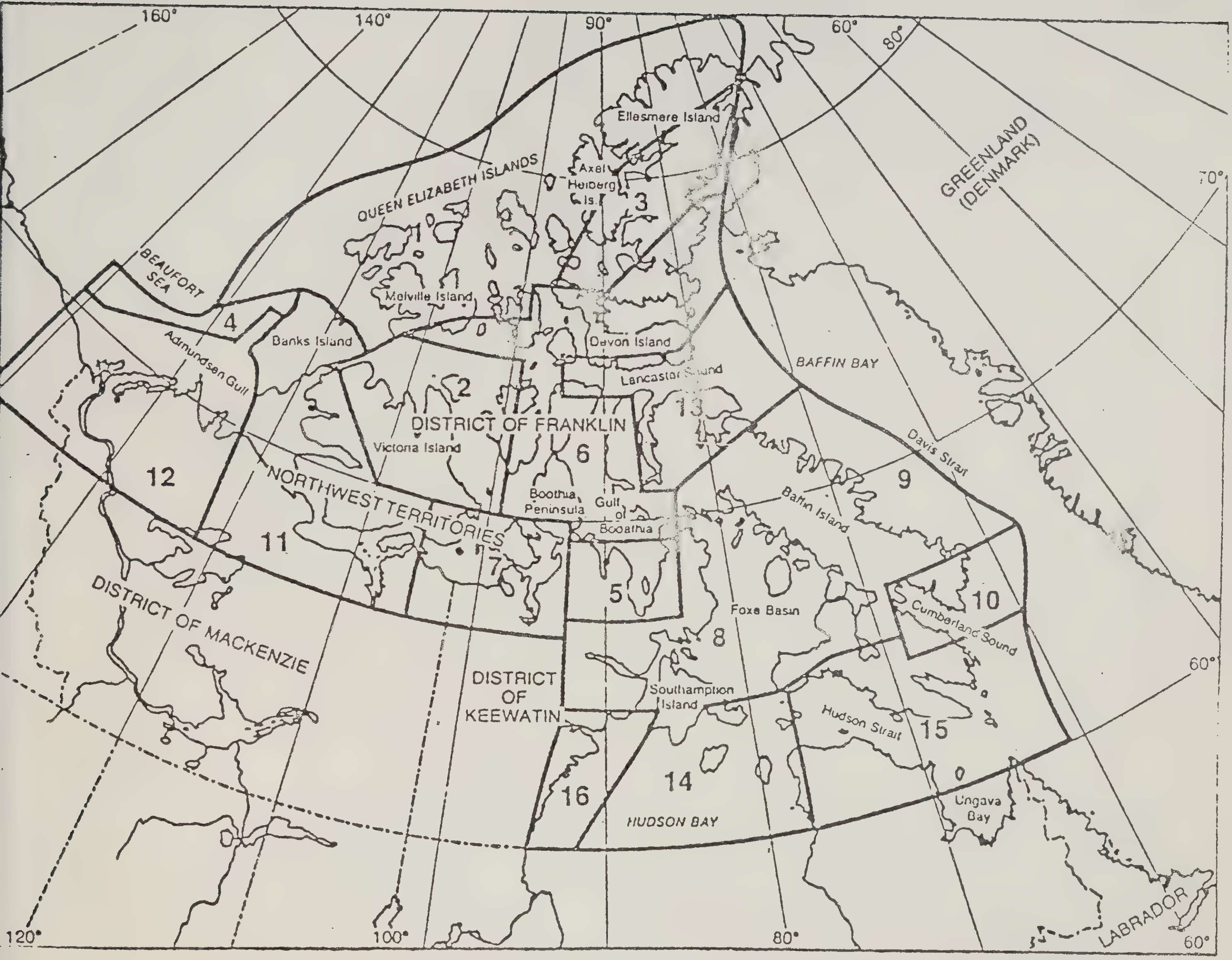


FIGURE 9. - Arctic Waters Pollution Prevention Act Shipping Safety Control Zones

The COGDR (administered by COGLA) and NLPDR (administered by NLPD) requirements for communication equipment on drilling units, in all important aspects, are identical. Both require compliance with the CSA and AWPPA regulations and also require the following:

i) a marine radio telephone (must be VHF according to COGLA),
ii) a single side band radio,
iii) a VHF aviation radio,
iv) a low frequency radio having beacon,
v) a radio capable communicating with any support craft used in connection with the drilling operation, and,
vi) a facility for transmitting written data to and from the shore base,
vii) maintenance of radio logs (NLPD specific while COGLA general through the CSA),
viii) provision of emergency electric power (storage batteries) for at least twenty-four (24) continuous hours of radio operation (COGLA is specific in that the marine radio must be that required under the SSRR for transmitting or receiving on the distress frequency, while NLPD is general)
ix) internal communications (See Appendices C and D for Details).

The Newfoundland regulations do not specify that conversations be taped in diving operations whereas the COGDR do. Under the revised winter drilling guidelines the Newfoundland regulations specify that a standby vessel must maintain regular communication with the drilling unit and during storm conditions communications must be established, at least hourly, with status reports given and logged during each communication. This is not specified in the COGDR.

With regard to lifesaving equipment, the COGDR necessitated the addition of a water resistant emergency radio capable of communicating with rescue vessels, helicopters and drilling units, and an emergency locater transmitter. The Newfoundland regulations do not specify that the radio (in this case called a marine radio) be water resistant or to whom it should be capable of communicating. Also they do not require the use of an emergency locator transmitter. Additional

Newfoundland regulations require that communication systems for real time weather and sea state information and data transfer be established among drilling units, and that all HF communications between drilling units and support craft and the operator's shore base be recorded on suitable recording equipment.

3.3 Regulations In Other Offshore Areas

The communications needs for other offshore areas are basically the same as those for the study area stated in Section 3.1 (Hyatt 1980; Hill, 1980; OST, 1981). Some of the applicable national regulations in other exploration areas such as the North Sea (e.g. Danish, British, and Norwegian regulations given in Appendix E, F, and G) are more general in terms of exact equipment requirements, but do concentrate on procedures. For example two requirements specifically stated in these regulations are the capability for à drilling platform to maintain communications with a shore station and the need for shutting down communications systems that may pose a hazard in certain operations. The Norwegian Regulations give the most detailed requirements for internal communications.

The Norwegian rigs also are separately classed as Mobile Drilling Platforms and are issued safety Radio installation certificates in accordance to that class. Examination of this certification does not suggest, however, that these regulations are any more stringent than those of the SOLAS convention.

The United States have no specific communications regulations for drilling rigs. The only requirement is that they comply with the SOLAS convention as cargo ships.

4.0 CURRENT COMMUNICATIONS SYSTEMS IN STUDY AREA

4.1 Means of Communications

Radio waves are used for communicating between two points. These waves may be propagated from the transmitting antenna to the receiving antenna through or along the surface of the earth, through the atmosphere, or by reflection or scattering from natural or artificial reflectors. Their propagation characteristics are dependent on frequency. Under the Radio Regulations of the International Telecommunications Union (ITU), the electromagnetic or radio spectrum has been divided into frequency bands; the relevant bands are given below:

Very Low Frequency (VLF) 3-30 Kilohertz (KHz)
Low Frequency (LF) 30-300 KHz
Medium Frequency (MF) 300 KHz - 3 Megahertz (MHz)
High Frequency (HF) 3 MHz - 30 MHz
Very High Frequency (VHF) 30-300 MHz
Ultra High Frequency (UHF) 300 MHz-3 Gigahertz (GHz)
Super High Frequency (SHF) 3 GHz-30 GHz.

Frequencies in the range of 300 MHz to 300 GHz are sometimes referred to being in the microwave band. Also, it is a common practice to include the 2 to 3 MHz frequency range within the HF band. Each of the listed bands are used on a shared basis by various radio services. Certain portions of each band, by ITU convention, are reserved for exclusive use by designated services (e.g. Land, Marine, and Aeronautical Communications-Fixed or Mobile; Navigation; and Location). Similarly, specific frequencies are designated for specific applications under ITU and Canadian conventions. A relevant example is provided in Table 10 which lists Canadian Maritime Mobile safety and Communications frequencies.

The frequencies listed in Table 10 are those in general use by ships in Canadian waters for intership communications and for ship/shore communications with radio stations operated by the Canadian

Frequencies		Channel	
Ship KHz	Coast KHz	Numbers	Purpose and Remarks
425 454 468 480 512	Normally one frequency between 415 and 490 as assigned		Public Correspondence
500	500		International distress and calling
2118	2514	57	Public Correspondence
2134		60	Intership (fishing vessels only)
2142	2538	61	Public Correspondence (S and NE Coast Nfld., Labrador & Atlantic Coast)
2182	2182	51	International distress and calling
2206	2582	59	Public Correspondence
2237		67	Intership (other than fishing vessels)
	2598	75	Weather & dangers to navigation broadcasts
2738		77	Intership (shared with US vessels)
4081.6	4376.0	407	Public Correspondence
4084.7	4379.1	408	Public Correspondence
155.3		6	Intership Safety
156.4		8	Intership Safety
156.80	156.80	16	International distress, safety and calling
	161.65	21B	Weather and dangers to navigation broadcasts
157.300	161.900	26	Public Correspondence

TABLE 10. Canadian Maritime Mobile Safety and Communication Frequencies (From CCG, NR, 1981)

Coast Guard, Newfoundland Region (CCG, NR, 1981). The channel numbers, shown against frequencies in the 2 MHz band, have no international status, while those in the bands above 4 MHz, including the Maritime Mobile VHF band, are recognized internationally. The Canadian Coast Guard has a network of 52 radio stations in Canada (the east coast locations are shown in Figure 8) with the chief function of providing a comprehensive safety communications service to ships on MF, HF, and VHF bands in accordance with SOLAS. Thus, internationally designated distress and calling frequencies are monitored continuously at these stations, which also provide a public correspondence radio telephone and radio telegraph service to shipping by interfacing the radio signals from a ship to various destinations in Canada and in other countries through switched networks of land lines, under sea cables and satellite circuits.

Thus, each of the frequency bands from VLF to SHF is usable, depending on a particular application. The parameters which influence choice of a frequency or band are the communication path length and the electrical properties of the medium along the path. The electrical properties of the ground (land and water), such as the conductivity and dielectric constant, vary considerably from those of the atmosphere. At very low frequencies, ground waves (waves through or along the surface of the earth, also called surface waves) may be satisfactorily propagate for distances of several thousand kilometers. At high frequencies, losses are so great that signals can be propagated for only a few hundred kilometers by ground waves.

Propagation in the MF and HF bands is chiefly by ground wave and reflection from the ionosphere, and severe fading (loss of signal) is caused in these frequency bands by the interference between gound and ionospheric waves at certain distances. At these and higher frequencies the ray path bending properties of the atmosphere (due to a change in the atmospheric refractive index with height) are used to provide satisfactory direct communications up to several times the line-of-sight distance. Thus, the MF and HF bands are being utilized for long range communications beyond the horizon while the VHF and higher frequencies are employed for short distances such as over the

line-of-sight distance. The UHF and EHF bands are being used for satellite communications as outlined in following section.

Radio frequency is the most important parameter effecting communications, as other parameters, which effect the quality and quantity of communications, are also dependent on it. For example, the electrical properties (conductive and dielectric) of the earth and atmosphere are frequency dependent and the intensity of man made and other noise against which communication signals must compete is also a function of frequency. The size and effectiveness (gain or efficiency) of antennas (e.g. parabolic dishes, horizontal wires, and vertical whips) which are used for radiating radio waves into space and subsequently capturing (receiving) these waves from space are very much dependent on frequency. It is a common practice to define or specify an antenna size on the scale of the wavelength (wavelength, = speed of light (3 x 10^8 m/s) / frequency). Thus, higher frequencies mean shorter wavelengths which for a given antenna size mean larger antenna gains. Or in general, bigger antennas mean larger gains for a given frequency or wavelength. High frequencies or short wavelengths are desirable because they employ antennas of reasonable size. For example, a half-wave length antenna at 3 MHz (= 100 m) is 50 m long while the corresponding antenna length at 500 KHz (= 600 m) is 300 m.

It is a common practice to define the utility or effectiveness of a particular communication link in terms of its reliability. Reliability is defined as the percentage of time the signal-to-noise ratio at the receiving end will exceed a specific value. The signal (desired information) to noise (undesired interference) ratio (usually defined in decibels (db)) provides a quantitative measure for the quality of received message. For broadcast quality receptions 38 db signal to noise is needed whereas for telegraphy (75 bits per second transfer rate) 2 db signal to noise ratio is adequate. For 90 percent intelligibility of speech, a signal to noise ratio of at least 14 db is required.

The noise level affecting the communication quality is dependent on the bandwidth of the signal or information being communicated. An increase in the signal bandwidth generally means an increase in the interfering noise. The bandwidth is a measure of the rate of transfer of signal, data, or information. For example, the continuous wave morse code telegraphy (A 2 emission of Table 9) which transfers 25 words per minute requires a bandwidth of at least 75 Hz for nonfading circuits and 100 Hz for fading circuits. Similarly, for double-side band or two-independent sideband telephony, a bandwidth of 6 KHz is necessary whereas the single-sideband telephony only requires 3 KHz bandwidth. For broadcasting of speech and music bandwidths of 8 to 20 KHz may be required, depending on the quality desired. Fascimile transmissions require a bandwidth of 5.45 KHz or 25.45 KHz, respectively, depending on whether amplitude or frequency modulation is employed.

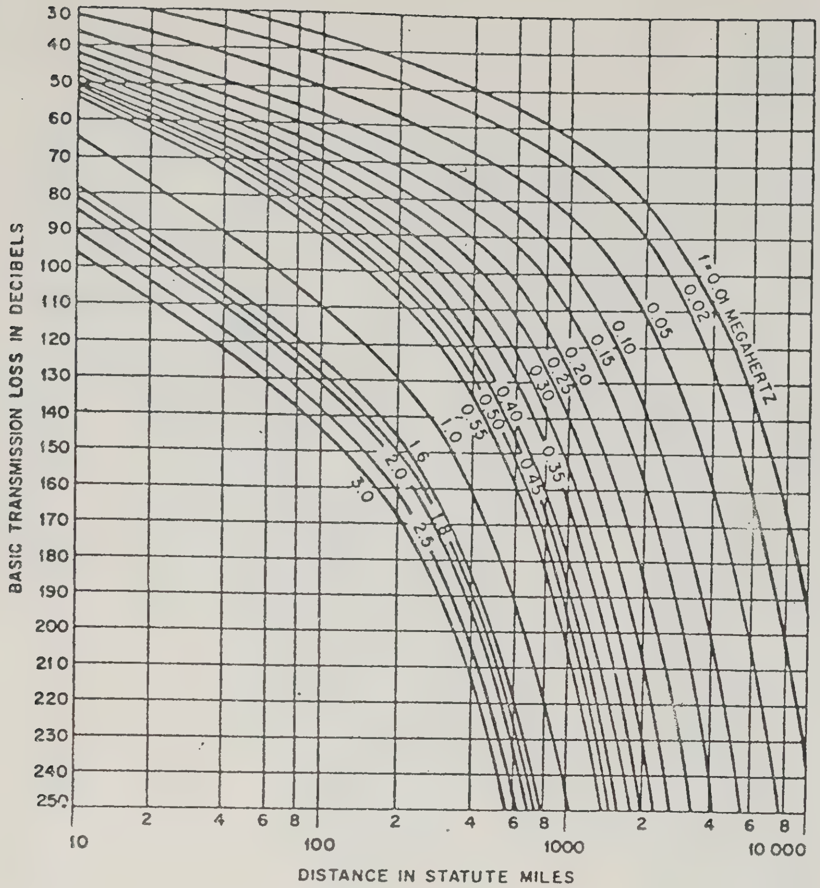
4.1.1 Medium and High Frequencies

The low and very low frequencies are primarily used for maritime radio navigation (e.g. LORAN-C transmissions at 100 kHz are used by ships to locate their positions) whereas medium and high frequency bands find increasing use in long range communications. The MF and HF bands are the primary means in the study area and elsewhere for communicating over distances several times greater than the line-of-sight distance (line-of-sight distance, depending on the heights of the communicating points, is typically less than 70 km).

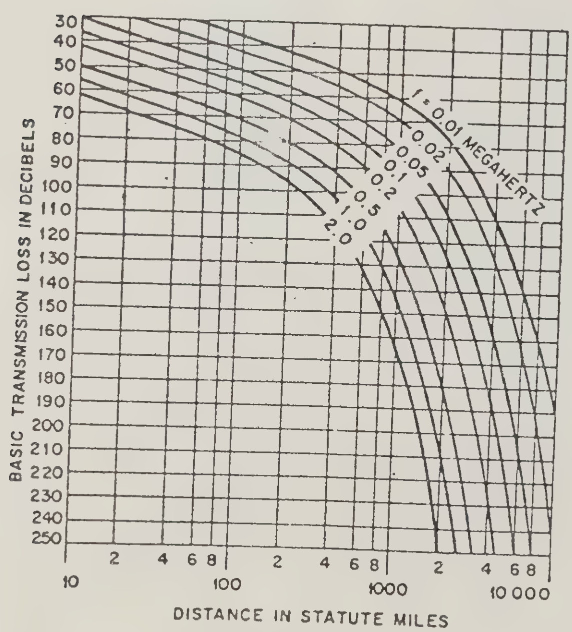
The basic transmission loss, also called path loss, is found convenient for analysis of radio communication systems. Small path losses are required for effective communications. The basic transmission losses for surface-wave or ground-wave propagation over land and sea water are plotted in Figure 10 for low and medium frequencies. These plots are for vertical polarization (relevant to vertical whip antennas commonly used in offshore installations) where both antennas (transmit and receive) are 30 ft (10 m) above the surface. At the stated frequencies, propagation losses for horizontally polarized transmission between antennas (relevant to horizontal wise antennas) on the surface of the earth are impractically high.

Figure 10, which does not include the effect of skywaves reflected from the ionosphere, indicates smaller loss and thus greater distance for transmissions over sea water in comparison with over land. This effect is due to a higher conductivity of sea water (5 mhos/m) as compared with that of land (0.005 mhos/m). Sky waves cause fading at medium distances and produce higher field strengths than the surface wave at longer distances, particularly at night. Sky-wave field strength is subject to diurnal, seasonal, and irregular variations due to changing properties of the ionosphere.

At frequencies between about 3 and 25 MHz (HF band) and distances greater than about 200 km, transmission depends chiefly on sky waves reflected from the ionosphere (Figure 11). The ionosphere is a region



(a)



(b)

FIGURE 10 Basic Transmission Loss Expected for Surface Waves Propagated Over a Smooth Spherical Earth Vertical Polarzation (a) Over Land (b) Over Sea Water (From Reference Data for Radio Engineers, 1972).

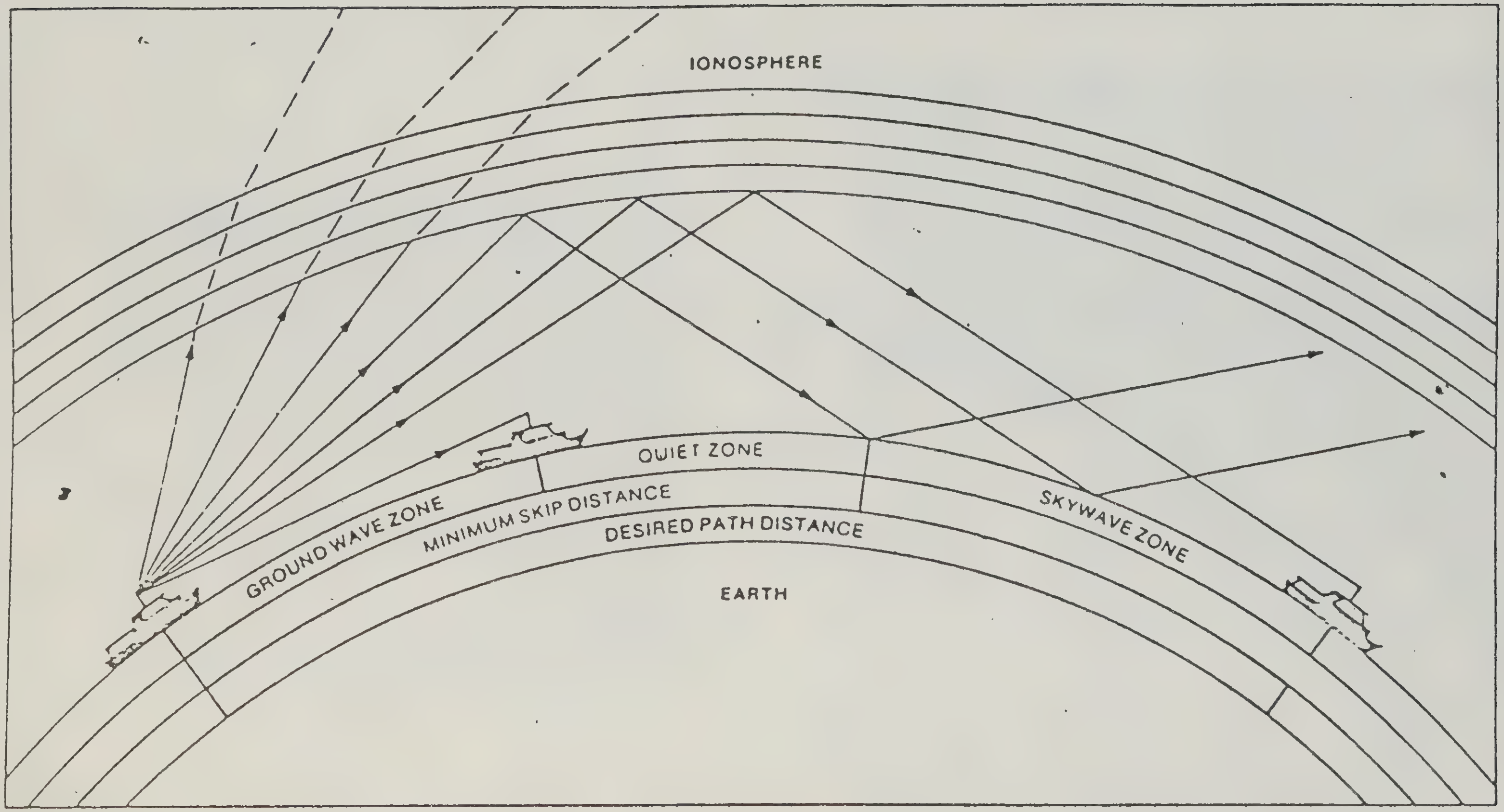


FIGURE 11. Schematic Explanation of Ground-Wave and Sky-Wave (Reflected from Ionosphere) Signal Zones

high above the earth's surface where the rarefied air is sufficiently ionized (primarily by ultraviolet sunlight) to reflect or absorb radiowaves. The ionosphere is usually considered as consisting of several layers at various heights (Layers D - 50 to 90 km, E - 110 km, F_1 - 175 to 250 km, and F_2 - 250 to 400 km). The D and F_1 layers exists only during night and the F_1 layer merges with the F_2 layer during the night at a height of about 300 km. The ionization density (which determines absorption and reflection properties of each layer) for the D and E layers corresponds with the elevation of the sun. In the F_2 layer, the ionization is independent of sun elevation but it and the layer height vary diurnally, seasonally, and over the sunspot cycle. Depending on the ionization density at each layer, there is a critical or highest frequency f_c at which the layer reflects a vertically incident wave. Frequencies higher than f_c pass through the layer at vertical incidence. At oblique incidence, the maximum usable frequency is given by:

$$MUF = kf_c \operatorname{Sec}\emptyset$$

where, k is correction factor (equal to 1 for short distances) that is a function of distance and vertical distribution of ionization and $\emptyset$ is the angle of incidence at reflecting layer (Figure 12). The critical frequency f_c and height, and hence $\emptyset$ for a given distance vary for each layer with local time of day, season, latitude, and throughout the 11-year sunspot cycle. The various layers change in different ways with these parameters. In addition, ionization is subject to frequent abnormal variations. The E layer is important for HF daytime propagation at distances less than 2000 km and for MF nightime propagation at distances in excess of about 200 km. The F_2 layer is the principal reflecting region for long-distance communication. The nightime field intensities (signal strength) and noise generally tend to be higher than during daylight due to the absence of the F_1 layer and reduction in absorption of the E layer.

In medium and high-frequency transmission, the communication bandwidth is limited by multipath propagation. The greatest limitation occurs when two or more paths exist with a different number of hops.

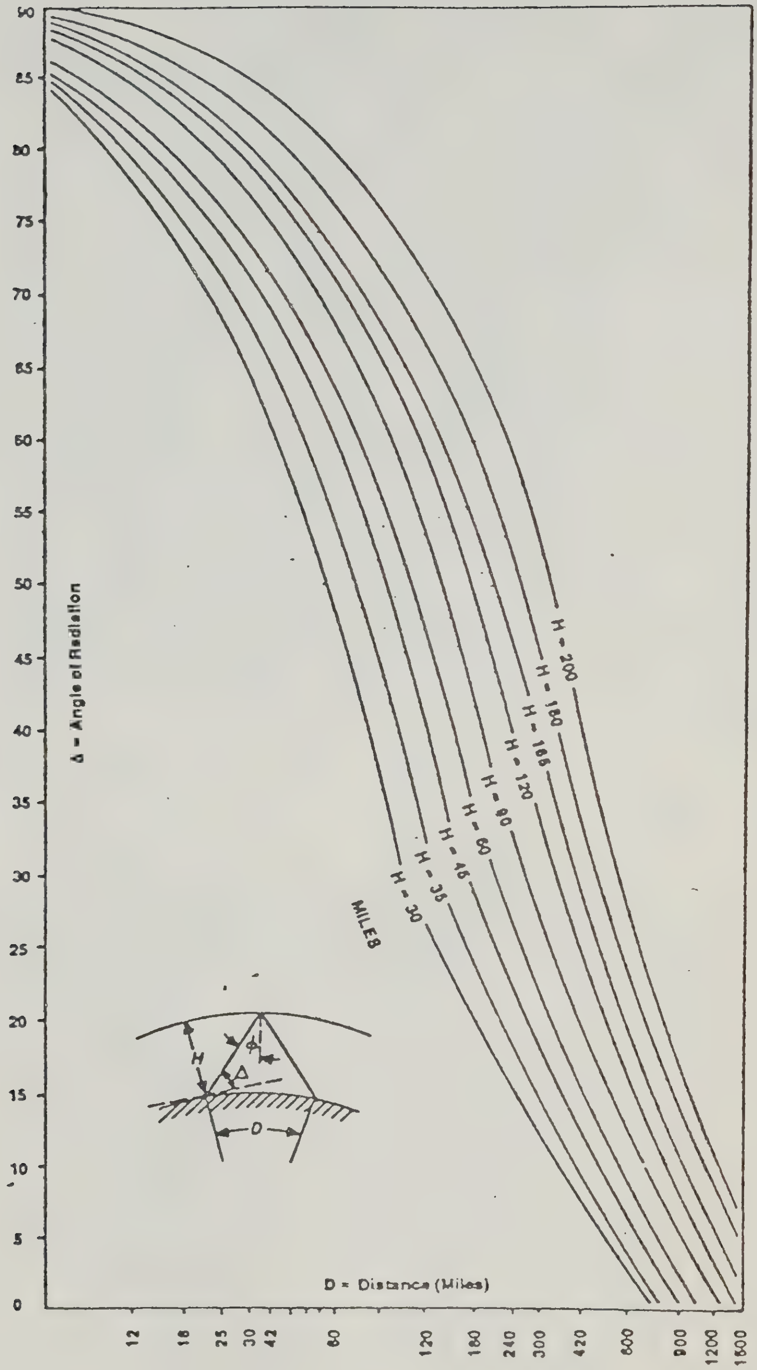


FIGURE 12. Radiation Angle (degree) Vs. Distance As a Function of Ionospheric Reflecting Layer Height

The bandwidth may then be as small as 100 Hz. To obtain bandwidths greater than, say, 1 kHz for paths less than about 600 km, operation at a frequency within approximately 10 percent of the MUF is necessary. The fading of the signal strength due to multipath propagation and ionospheric variations effects communications quality. However, if two or more high frequency radio channels are sufficiently separated in space, frequency, angle of arrival, time, or polarization, the fading on the various channels is more or less independent. This diversity, obtained by using appropriate systems, is commonly employed to improve the overall performance on a single HF circuit by combining or selecting separate radio channels.

A number of programs or procedures are available to predict performance of a HF communication system and to determine optimum frequencies for use (Haagensen, 1981). Petrie and Campbell (1974) have estimated reliability of HF communications links between a drilling vessel and a shore station at various distances in a study commissioned by the East Coast Petroleum operators (EPOA) and the Communications Research Centre (CRC) of the Canadian Department of Communications. Their computed reliability values for sky-wave communications are shown in Table 11 for two orientations of the 35 ft whip antenna on a drilling vessel. These values were calculated assuming a requirement of voice communications with 15 db signal-to-noise ratio in a 3 kHz bandwidth over 24 hours of the day. The circuit was assumed to have available every megahertz (MHz) frequency in the band from 2 to 7 MHz with an additional frequency near 8 MHz for the long-distance circuit. The expected reliability of a ground-wave communications at 2 MHz is shown in Figure 13 which indicates high reliability for over a sea water path for distances less than 300 km during night-time and less than 600 km during day-time.

The MF band contains the International distress and calling frequencies of 500 KHz and 2182 KHz, respectively, for telegraphy (Morse Code) and telephony. To improve the efficiency of the maritime communications services, the Canadian Department of Communications (TRC-11, 1977) only allows single sideband emissions (reduced carrier A3A or suppressed carrier A3J) in all bands below 23,000 KHz (or 23

Circuit	Distance (km)	Month	Reliability (per cent) (a)	Reliability (per cent) (b)
Drilling Vessel-Shore Station	250	June	47	72
		December	82	99
Drilling Vessel-Shore Station	500	June	67	73
		December	78	96
Drilling Vessel-Shore Station	1000	June	74	63
		December	83	94

TABLE 11. Expected Reliability of Sky-Wave Links for Two Orientation of 35 ft Whip Antenna on a Drilling Unit (a) Vertical (b) Inclined 45° from Vertical. (From Petrie and Campbell, 1974).

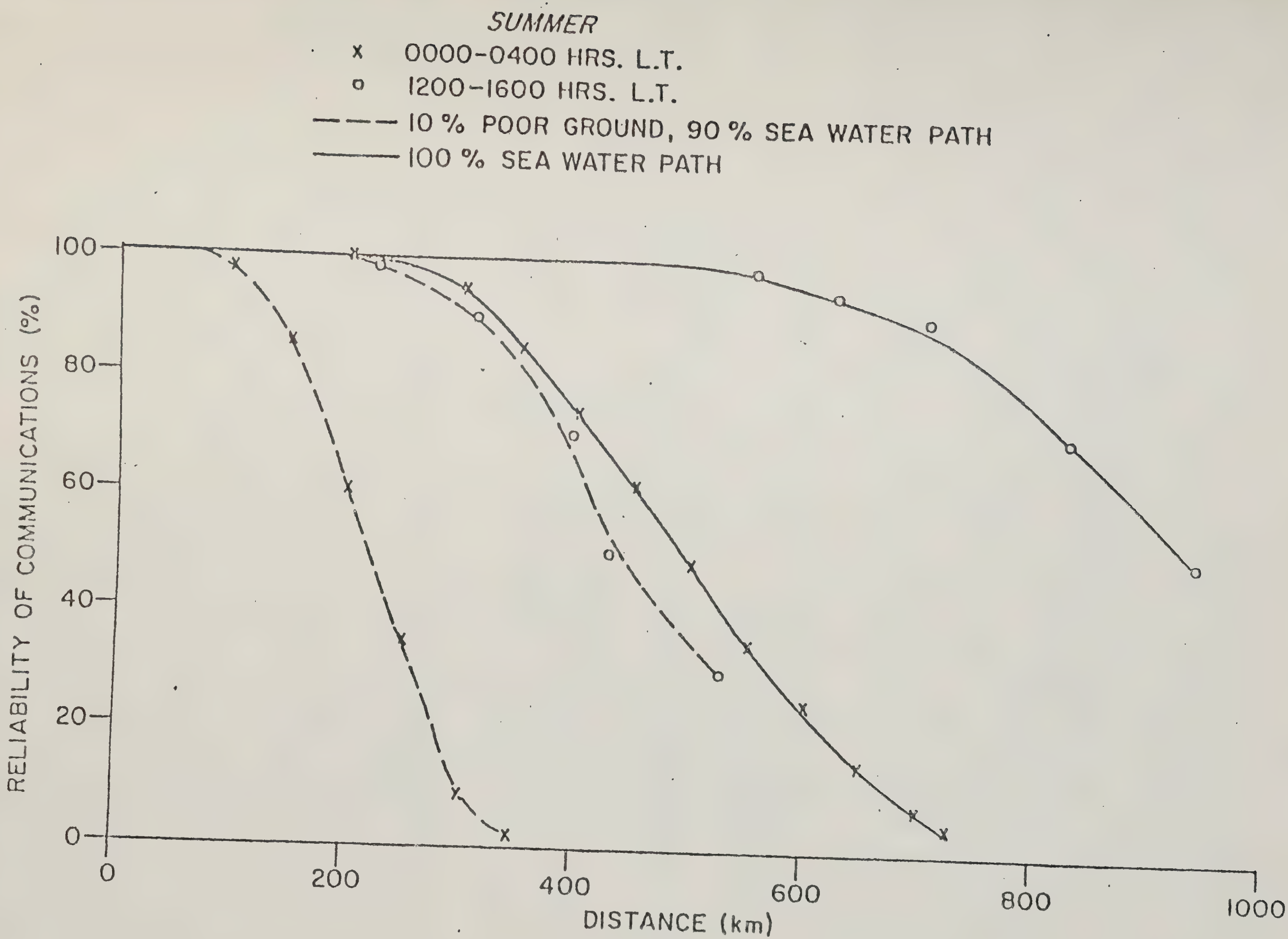


FIGURE 13. Expected Reliability of a Radio Telephone Link Using Ground-Wave Propagation at 2MHZ (From Petrie and Campbell, 1974)

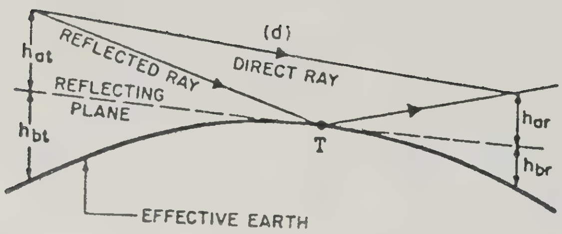
MHz). The double sideband emissions have been phased out. At MF and HF bands, Canadian Coast Guard provides ship/shore communications service through coast stations (Figure 8 and Table 10). Non-safety ship/shore communications can be provided through private shore facilities through proper licensing. Six frequencies in the 2 MHz range of the MF band are available for private ship/shore and intership single sideband communications, on a shared basis between Canada and the United States (Dept. of Communications, TRC-14, 1977). Only 2.8A3A and 2.8A3J emissions are allowed on these frequencies (2.8 is the bandwidth in KHz). Details of the specific frequencies involved in the 4, 6, 8, 12, 16, and 20 MHz bands are also included in the TRC-14 document.

4.1.2 Very High Frequencies

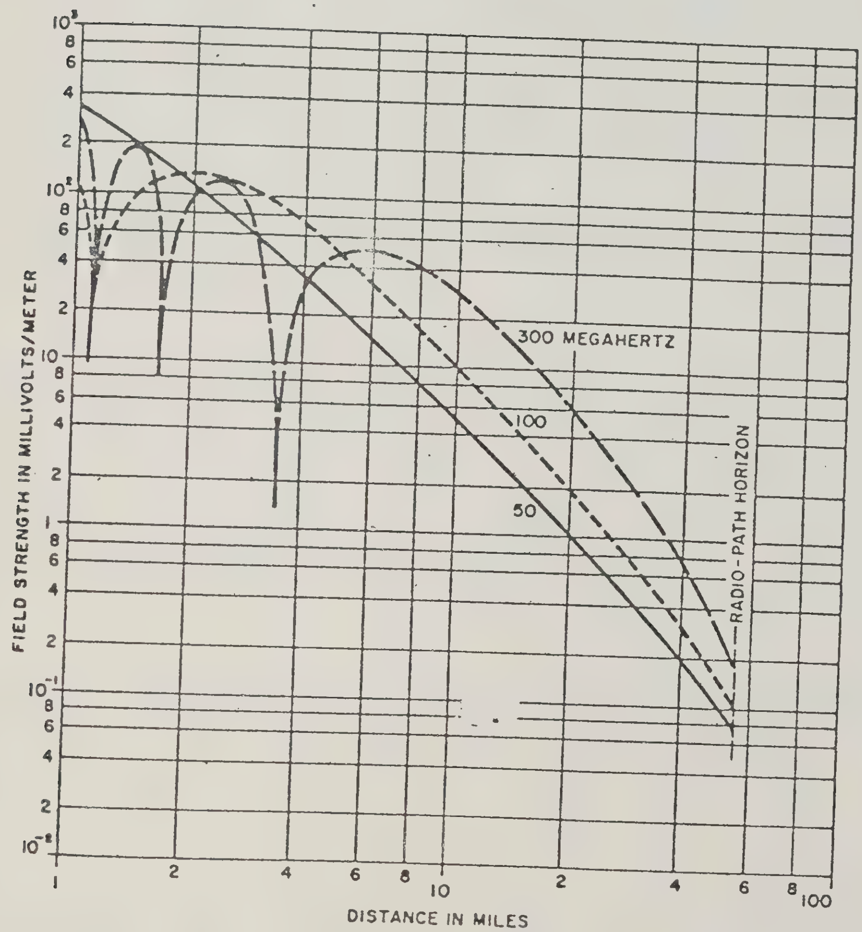
The VHF and higher frequency bands are used for line-of-sight communications. The decrease of the atmospheric refractive index with height, results in the bending of radio rays. Uniform bending may be represented by straight-line propagation, but with the radius of the earth modified so that the relative curvature between the ray and the earth remains unchanged.

The distance in miles to the radio horizon over smooth earth, when the antenna height (in ft) is very small compared with the earth's radius, is given by $(3\ kh/2)^{1/2}$, where K is the effective radius factor (typically about 1.33 in temperate climates, however, values from about 0.6 to 5 are to be expected). The two antennas (transmitting and receiving) at heights of h_t (ft) and h_r (ft) are in radio line-of-sight provided the spacing in miles is less than $(2h_t)^{1/2} + (2\ h_r)^{1/2}$ (assuming K = 1.33). As examples, the radio horizon for a transmitting antenna at a height of 500 ft is at about 34 miles (55 km) while the maximum radio path length with a receiving antenna at a height of 60 ft is approximately 42 miles (67 km).

There are usually two path lengths between a transmitting and a receiving antenna; one, a direct path (free-space wave) and the other, ground-reflected wave (Figure 14). These two rays or waves combine to



(a)



(b)

FIGURE 14 (a) Interference Between Direct and Reflected Rays, and, (b) Variation of Resultant Signal with Distance and Frequency. (From Reference Data for Radio Engineers, 1972)

produce an interference pattern (adding when in phase and subtracting when out-of-phase). The variation of the resultant electric field (signal) strength with distance and frequency (Figure 14) shows increases in field strength as well as severe fading (loss of signal). For transmission paths of the order of 30 miles and for frequencies up to about 6000 MHz (6 GHz), possible increases of signal strength may be up to 10 db with respect to free-space propagation while the fading margin required may be up to 40 db to achieve reliability levels of 99.99 percent. Space or frequency diversity techniques must be employed to reduce signal fading due to reflection multi-paths or atmospheric multi-paths (due to variations in refractive index which introduce relative rapid fading).

The VHF band contains the international distress and calling frequency of 156.8 MHz (Channel 16) for maritime use. The band of 156 to 174 MHz has been reserved for the maritime mobile service by the Canadian Department of Communications (TRC-13, 1980). Different Channels, with 25 kHz channeling separations, are assigned for intership and ship/shore communications for public correspondence, and for commercial or Coast Guard use. The frequency of 156.3 MHz may be used for communication between ship stations and aircraft stations engaged in coordinated search and rescue operations. Emergency Position Indicator Beacon (EPIRB) being developed is expected to employ the frequency of 156.75 MHz.

The VHF band also contains the frequencies of 243 MHz and 121.5 MHz, reserved, respectively, for survival craft and equipment and aeronautical search and rescue operations. Both are aeronautical distress frequencies. In addition, VHF band is being used for on-board ship station communications provided the radiated power (signal level) does not exceed 1 watt. The VHF aeronautical band allows coordinations of the helicopter movements. The use of VHF band allows employment of small and yet directional antennas. Still smaller antennas are employed at UHF and higher frequency bands. Due to their relatively short range use, VHF transmissions normally utilize powers of 100 watts or less as compared to 500 and 1000 watts for HF transmissions.

4.1.3 Satellites

Satellite communications systems are finding increasing usage and importance in the offshore communications network. A satellite in a geostationary orbits around the earth (36,000 km above the equator) provides a stable relay or repeater station for connecting two points on the earth which are within its view. Thus, the two points separated by a large distance can communicate through the common satellite station which acts as an intermediany (repeater or relay station) and provides a direct access to each point. In recognition of this benefit, a global system of satellites was established by the International Maritime Satellite Organization (INMARSAT) beginning in 1976 to provide global maritime communications (intership and ship/shore). INMARSAT is presently owned by a consortium of 37 countries where the shares of each country is intended to reflect that country's actual usage of the system. Canada has an ownership of approximately 2.6 percent of the shares issued, through Teleglobe Canada, a crown corporation.

The INMARSAT space segment consists of a number of satellites, both operational and spare, deployed over the world's three main oceans (Atlantic, Pacific, and Indian) - together with the tracking, telemetry, command, monitoring and related facilities and equipment needed to support them. Each satellite has a capacity equivalent to about 30 telephone channels. Each can be assessed by a line-of-sight transmission path by a station located within the foot print of the satellites (Figure 15). Two stations located within the same satellite footprint can be connected by a link which is reliable and of very high quality.

The INMARSAT (SATCOM) equipped ships and offshore facilities operating in the Atlantic Ocean region (the coverage only extends up to approximately 70°N as per see Figure 15 for the Satellite footprint) can dial directly into the Canadian public (telephone) network. The ship-to-shore calls are routed via Teleglobe Canada's International Switch in Montreal, Quebec, which in turn is linked to the Southbury, Connecticut, U.S.A. Coast Earth Station (one of three such stations around the world at present).

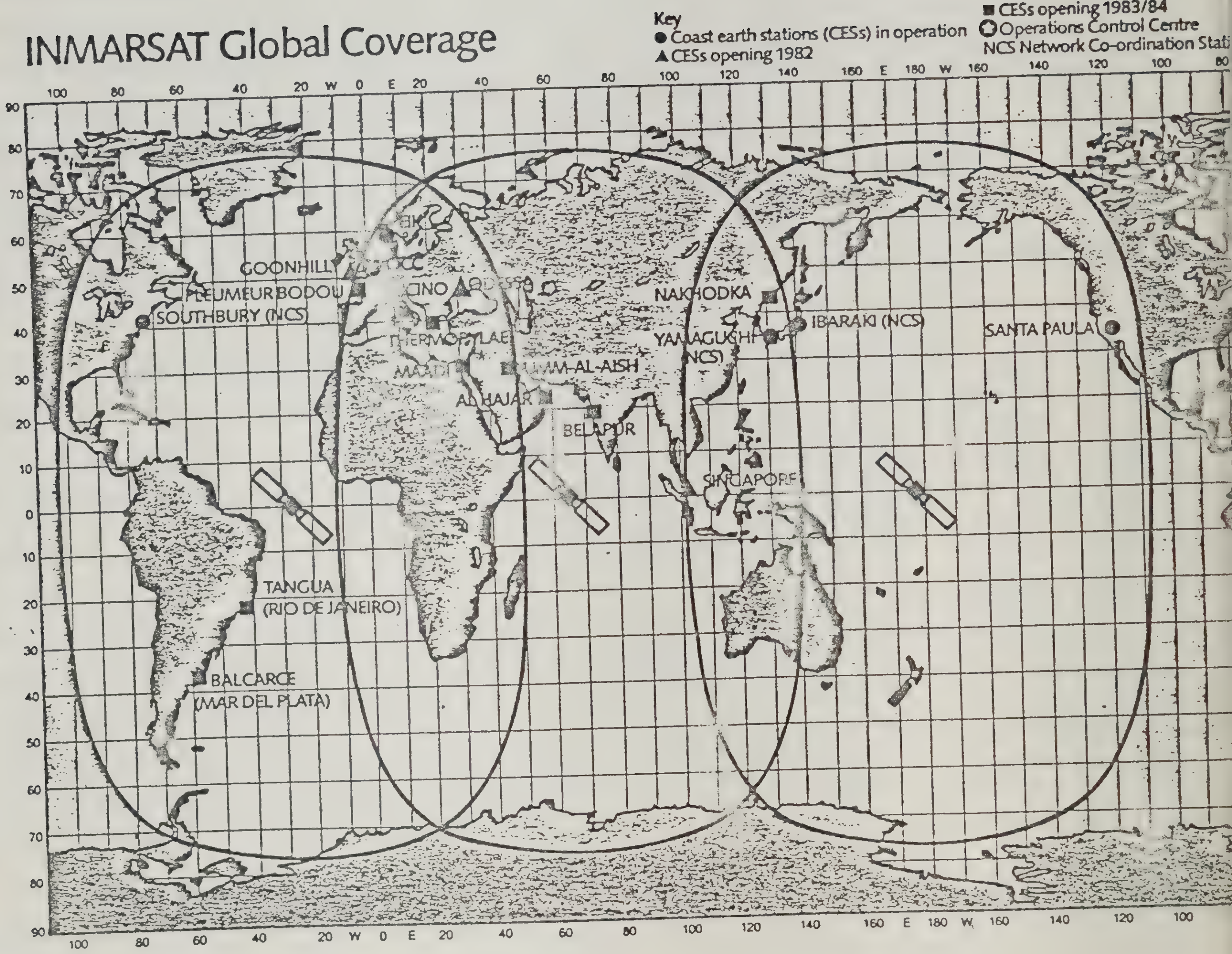


FIGURE 15. INMARSAT Global Coverage (Study Area Coverage Up To Approximately 70^{O}N).

Shore-to-Ship communications (Figure 16) are in the 6 GHz band from coast earth station to satellite and in the 1.5 GHz band from satellite to ship. Ship-to-shore communications are in the 1.6 GHz band from ship to satellite and in the 4 GHz band from satellite to coast earth station.

An INMARSAT ship earth station (sometimes called SATCOM terminal) includes a parabolic antenna of 1.2 m in diameter mounted on mechanical stabilizer with vertical emphasis and contained within a protective radome above deck. The antenna is automatically stabilized and can maintain contact with the satellite with ship rolls of up to 30^{o}. The remaining equipment is contained below deck. The range of services and facilities available from INMARSAT currently include:

i) fully automatic international telex, telegram, and telephone access,
ii) fascimile transmission,
iii) low to high-speed data link (high data rate of 56 Kbps available only ship to shore), and,
iv) distress, urgency and safety communications (distress alerts connected automatically and virtually instantaneously through emergency overide channel on each terminal.

The domestic or Canadian satellites available for offshore communications are the Telesat Canada Anik B, C, and D series. Each of the Anik B and D satellites provides full coverage over Canada, including the offshore drilling area and the Arctic and uses 6/4 GHz bands for up/down links. The minimum antenna size of 4 m needed to communicate at these frequencies, is impractical for installation on non-fixed drilling units. Antenna stabilization is required to maintain a precise antenna orientation with respect to the satellite so as to compensate for the motion of the drilling unit by wind and sea conditions (Table 5). While it is difficult to stabilize antennas of this size, fixed installations such as jack-up rigs and remote base camps can utilize communications services offered by the 6/4 GHz link.

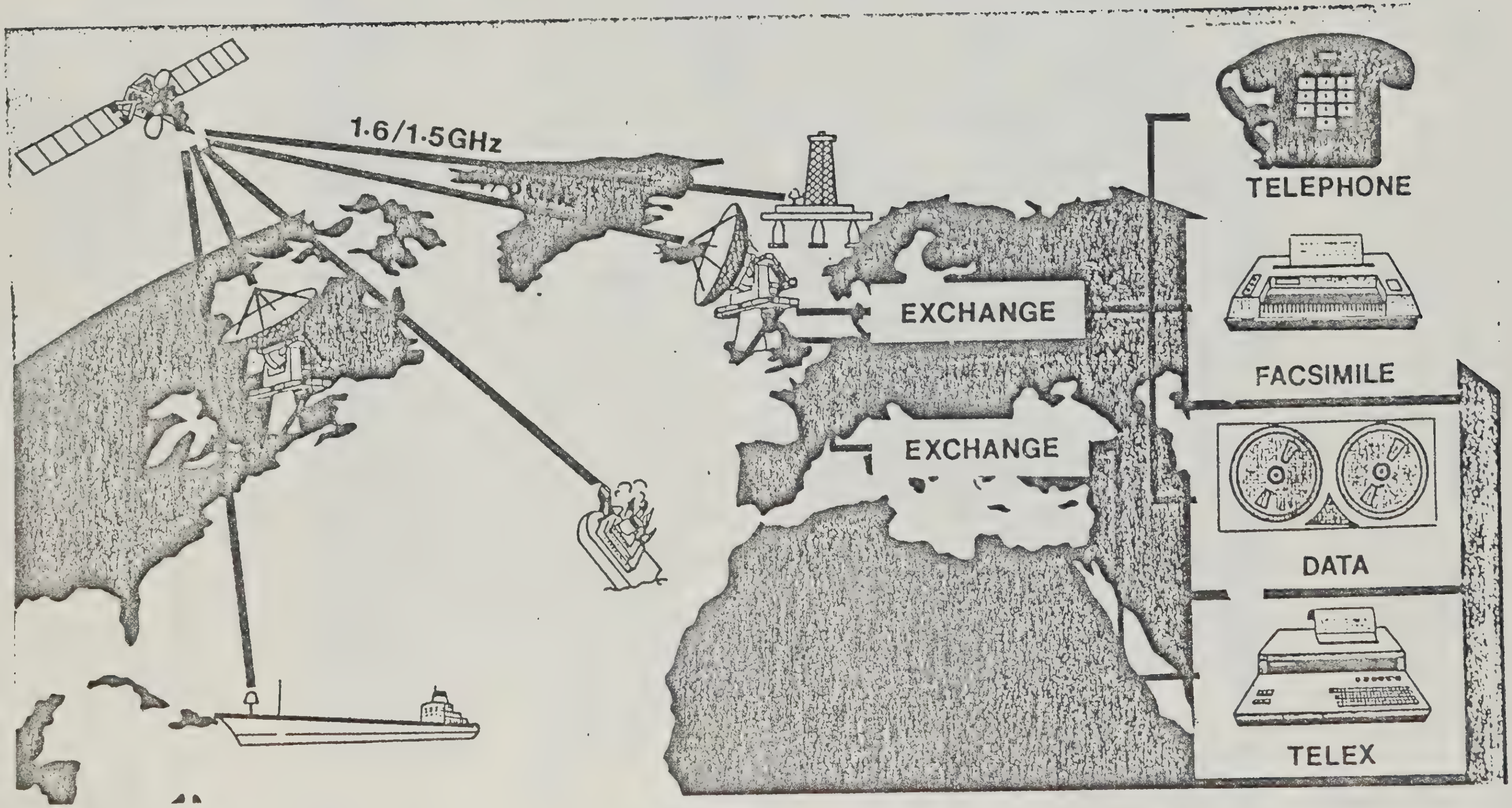


FIGURE 16. Satellite (INMARSAT) Communication Links and Services

Both Anik B and C satellites utilize the 14/12 GHz bands for up/down communication links and employ four spot beams. The coverage includes the entire Atlantic Canada area, with the exception of the northern half of Labrador. Very small (2 m) antennas can be used at these frequencies, providing practical means for access by semi-submersibles and drill ships. Newfoundland Telephone, in partnership with Memorial University, CRC, and Mobil Oil Company, has field tested a prototype 14/12 GHz stabilized satellite terminal and the results are encouraging (Tarrant, 1983).

4.1.4 Emergency

The order of priority for radio communications in the marine service is given to Distress Communications, Urgency Communications, and Safety Communications followed by all other communications. The distress signal ("May Day") is used only when there is an immediate danger of loss of life or property. The urgency communications signal ("PAN PAN") is used only when the safety of a person or a vessel is in jeopardy but there is no immediate danger. Safety signal ("Securite") is used to precede important navigational or meteorological warnings and by vessels approaching narrow intersections or transiting waters to announce their intentions on channel 16 (156.8 MHz) (CCG NR, 1981).

As noted earlier, all ship stations need to be fitted with radio telephone and/or radiotelegraph equipment based on their area of operation. The following International Distress, Safety and calling Frequencies are used:

i) 500 KHz (telegraphy),
ii) 2182 KHz (voice), and
iii) 156.8 MHz (voice).

The 2182 KHz and 156.8 MHz frequencies are primarily used for radiotelephone distress, urgency, and safety calls. However, they may be used for initial contacts and replies with other stations to establish communication following which a change to a working frequency must be made for the resumption of communications. All ship stations equipped to transmit on either or both of these frequencies maintain a listening watch on these frequencies (voluntarily or by law). All stations fitted with 2182 KHz unless in a distress situation must maintain radio silence while guarding 2182 KHz for three minutes twice each hour. Ship station radio installations require storage batteries to supply emergency power for continuous 6 hour operation while COGLA regulations require a back-up power for 24 hour operation.

All compulsory fitted vessels must carry a portable lifeboat radio apparatus which is usually fitted with the following frequencies:

Transmit 500 KHz (telegraphy), 2182 KHz (voice), and 8364 KHz (telegraph),

Receive 500 KHz (telegraphy), 2182 KHz (voice).

This radio apparatus is capable of transmitting the following signals automatically (Canadian Department of Communications, Atlantic Region Guide to Marine Telephone Operation):

a) International Radiotelegraph Auto-Alarm System

Signal is automatically transmitted prior to the distress signal and consists of twelve dashes, four seconds in duration separated by one second between dashes. When this signal is transmitted, it activates an "automatic alarm receiver" fitted in deep sea vessels which generally should receive the signal within a radius of up to 100 miles (160 km).

b) Radiotelegraph Distress Signal

It (SOS letters three times in Morse Code followed by two long dashes) is capable of being transmitted automatically (or manually) on the 500 KHz or 8364 KHz frequency following the radiotelegraph auto-alarm signal. The two long dashes are for direction finding purposes. Most portable lifeboat radios can receive on 500 KHz but not on 8364 KHz.

c) International Radiotelephone Alarm Signal

In most portable lifeboat radios it is usually transmitted automatically on the frequency 2182 KHz and should last thirty to sixty seconds. This signal, for the most effect, is sent during the silent periods at the hour and half hour and followed by spoken radiotelephone distress message.

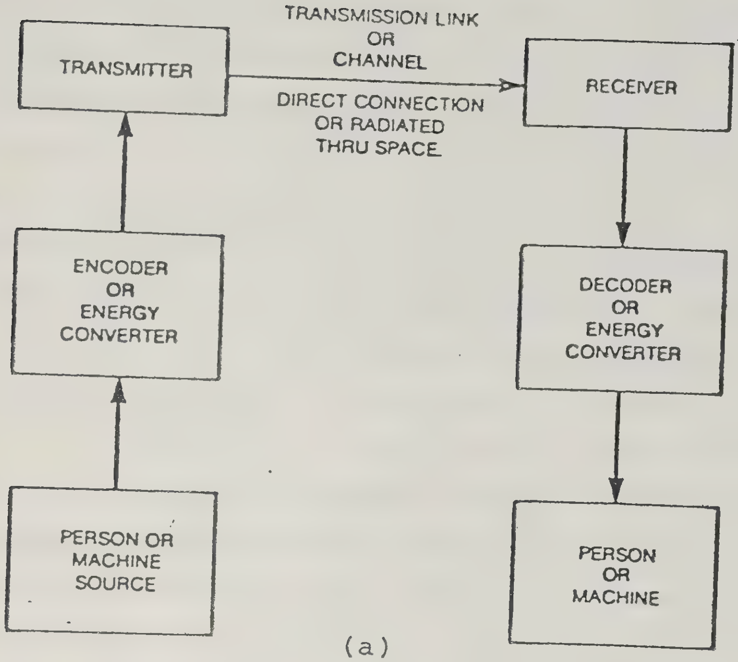
Some towing vessels are required to carry an Emergency Position Indicating Bouy (EPIB) which is radar reflective and designed to float free if the vessel sinks. The buoys are equipped with a radio transmitter capable of automatically transmitting on 121.5 MHz and 243 MHz (Aeronautical Distress Frequencies). Ship radio equipment is generally not fitted with a receiver to monitor 121.5 MHz which is in the VHF "aeronautic band".

Lead acid storage batteries are used extensively as a source of primary and/or emergency power for radio telephone equipment. Details of records of their maintenance and charging need to be kept. In addition to ship stations, Coast Guard Stations (Figure 8) maintain a continuous listening watch on emergency frequencies 2182 KHz (Channel #51), 156.8 MHz (Channel #16) and 500 KHz for distress, urgency and safety calls.

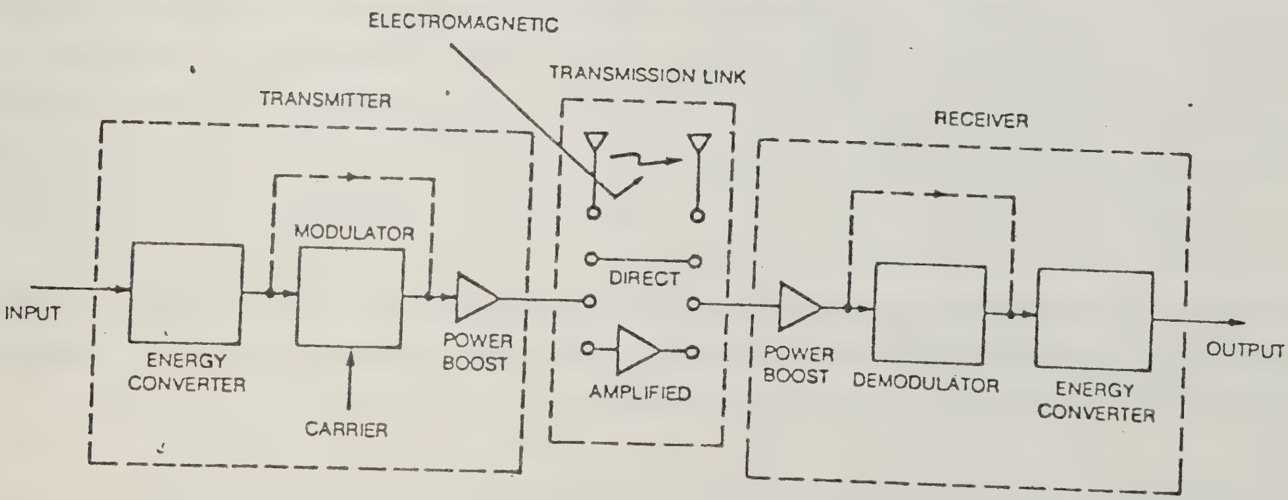
4.2 Communications Systems

The main elements of a communications system (Figure 17) are: energy converters (encoder and decoder), a transmitter, a receiver, and antennas (one for transmitting and one for receiving). The energy converter, as the name suggests, converts one form of energy into another (e.g., voice into electrical fluctuations or pulses and electrical pulses into voice as done by a microphone and a speaker, respectively). During the transmission phase, the electrical pulses (in the form of voltage or current fluctuations) are used to modulate a carrier wave of desired radio frequency (HF, VHF, etc.). Modulation is a process whereby certain characteristics (amplitude, frequency, or phase) of the carrier wave are varied in accordance with the message signal (electrical fluctuations from encoder). The carrier wave signal is provided by the transmitter and the modulated signal is generally boosted to desired power levels before transmission.

The modulated signal may be transmitted directly through a cable (as done in land-based telephone circuits) or through the atmosphere by propagation of electromagnetic waves. An antenna is used to radiate the transmission signal into space and another antenna is used at the



(a)



(b)

FIGURE 17. Communications Systems, (a) Main Elements and (b) System Configuration

receiver site to capture this radiation. The received modulated signal is amplified, demodulated, and converted back into the desired form (e.g., voice). The process of separating the modulating signal (message signal) from a modulated carrier wave is called demodulation or detection.

Three forms of amplitude modulation and frequency modulation are generally employed in offshore communications (Table 9). In amplitude modulation (AM), the frequency components of the modulating signal (e.g. voice with a typical associated frequency range of 300 Hz to 3000 Hz) are translated to occupy a different position in the spectrum. In conventional AM, the frequency spectrum of the modulated wave consists of a carrier frequency component, frequencies given by the addition of carrier frequency and frequency components of the modulating signal (known as upper sideband), and frequencies given by the subtraction of carrier frequency and frequency components of the modulating signal (upper sideband).

If, the carrier frequency component is suppressed from the AM waveform, the resulting Double-Sideband suppressed carrier (DSB-SC) signal is obtained. When the upper side band and carrier are completely removed from the conventional AM signal, a single side band (SSB) signal with suppressed carrier is achieved. As it carries all the necessary information contained in the message signal (due to containing all the frequency components of the modulating signal), the SSB is the preferred mode of communication where frequency spectrum needs to be preserved as when there are many users (SSB only requires half of the bandwidth needed for DSB).

The SSB communications offers several other advantages as well; e.g., relative immunity from selective fading, reduced noise, and reduced radiated power levels for a given effective signal strength. The frequency modulated (FM) communications in which the instantaneous frequency of the modulated signal is proportional to the modulating signal amplitude, provide even better signal-to-noise ratios than the SSB transmissions.

Some other aspects of a communications systems which influence its performance are the antenna characteristics, transmit power levels, and number of channels available. The most common antennas used in offshore installations are whips and wires which offer little or no gain and directionality. The power levels are dependent on frequency of operation and desired range and may vary from tens of watts to several kilowatts. A multi-channel capacity is normally available. All the communication hardware must meet standards in accordance with the Canadian regulations, approval before installation, and need to undergo yearly inspections.

An operational communications system is shown in Figure 18 indicating the possibility of controlling two drilling units from one base (e.g. located in St. John's) or the option of communications with two land stations from a drilling unit. A summary of communications systems used in the study area based on responses to our questionnaire is provided in Table 12. A drilling unit is usually equipped with one or more MF/HF circuit, one VHF marine circuit and one VHF aeronautical circuit for external communicatioins. In most cases, two independent MF/HF circuits are practically available; one to handle telex/telecopier, and the other to handle voice communications with the shore stations. Two circuits are provided so that one can act as a back-up; usually voice and telex messages are handled on the same circuit depending on level of traffic.

The MF/HF circuit is designed to operate in the frequency range from 1 to 30 MHz. Usually up to six private transmission frequencies arer assigned by the Department of Communications; generally at least one in each of the 2,4,6 and 8 MHz bands. The 2 MHz band may have two assigned frequencies. Two transmitters are normally available, each with a separate exciter which are remotely controlled. The main transmitter usually has a transmit power rating of 1 to 1.5 kw while the second transmitter, intended as a back-up, has a lower power rating typically around 400 w. Back-up or emergency power is provided for only operating the secondary transmitter over periods ranging from 20 to 40 hours. The transmitters can provide all the necessary emission types, ranging from single side band to AM modulted, if

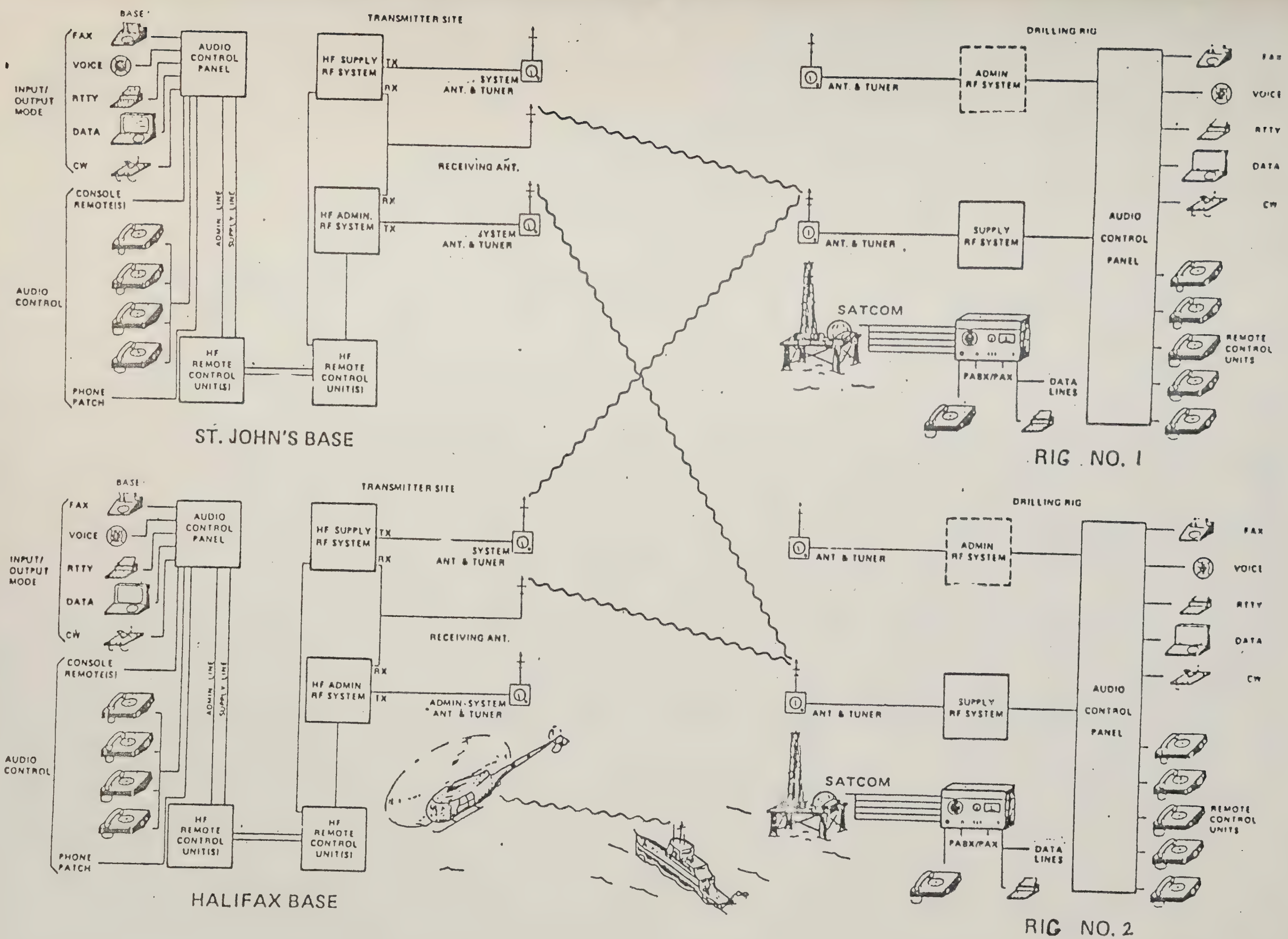


FIGURE 18. An Example of Offshore Communication Systems

Installation	Frequency Bands	Equipment			Operator		Traffic
		Band	Power out (W)	Emergency Power (Hrs.)	Yrs. Exp.	No. of Operators	
Base	6 Private HF	HF HF HF	125 1000 1000	10 (Battery)	2- 5	2	Medium
	8 Private HF	HF HF HF	125 1000 1000	Unlimited (Diesel)	1- 4	4	Medium
	7 HF 3 MF 3 VHF	HF MF VHF	1000 500 100	Unlimited (Diesel)	1-36	8	Heavy
	7 HF 3 MF 3 VHF	HF MF VHF	1000 1000 100	Unlimited (Diesel)	6-30	5	Medium
Drill Unit	6 Private HF VHF-M VHF-A	HF HF VHF-M VHF-A	600 200 25-1 10-1	20 (Battery)	1-20	2	Heavy
	8 Private HF VHF-M VHF-A	HF HF MF VHF-M VHF-A	150 400 400 25-1 20-1	5 (Battery)	1- 2	2	Heavy
	6 Private HF VHF-M VHF-A	HF HF VHF-M VMF-A	400 400 25-1 40-1	40 (Battery)	1-20	4	Heavy
	5 Private HF VMF-M VHF-A	HF VHF-M VMF-A	400 20-1 14-1	20 (Battery)	0.5-22	2	Heavy
Support Vessel	7 Private HF VHF-M	HF HF HF VHF-M VHF-M	400 100 100 25-1 25-1	40 (Battery)	1- 5	3	Low
	7 Private HF VHF-M	HF HF HF VHF-M VHF-M	400 400 100 25-1 25-1	20 (Battery)	1- 5	3	Low
Heli-copter	VHF-M VHF-A HF	VHF-M VHF-A HF	5-1 20 150	- - -	- - -	- - -	Low
	VHF-M VHF-A	VHF-M VHF-A	5-1 20	- -	- -	- -	Low
	VHF-M VHF-A HF	VHF-M VHF-A VHF-A HF	5-1 20 20 150	- - - -	- - - -	- - - -	Low

TABLE 12. Examples of Typical Communications System Parameters in the Study Area (HF band includes MF band, Private Frequencies are in Addition to Public Frequencies).

required. Each transmitter has multi-cahnnel (6 to 50 channels) capability available (referred to as a synthesizer) with auto-selection and tuning. Thus, the channel frequencies can be programmed in advance and called for use when needed. In some systems, the transmit channels are automatically scanned and a particular channel selected to suit the prevailing environmental conditions.

A drilling unit has more than one single selectable channel receivers operating at 300 KHz to 300 MHz range. Again, a number of channels can be programmed in advance and continuously scanned to indiicate active channels. The status of active channels is indicated by visual and audio alarms. The receivers have very good sensitivity (typically 0.1 μv for a s+n/n of 10 db) and some are equipped to suppress interfering noise automatically.

The drilling units usually has three MF/HF antennas; two vertical whips, each typically 35 feet long, and a wire antenna. The whips are provided with remote auot-tuning capability. One whip is usually intended to act as a spare or back-up. The antennas are fitted on the top deck of the drilling unit away from any tall, interfering structure. The remaining equipment is placed in the radio room which is usually on the second deck, right underneath the antenna location. The location of the radio and antennas varies from drilling unit to drilling unit. In drilling ships (dynamically positioned), the radio equipment is placed in the wheel-house or bridge. In semi-submersibles the radio room is fairly well integrated with other business related office activity.

The radio room on drilling units is fitted with panels containing thumb wheel and other switches which provide selections of different antenna, receiver, and transmitter combinations by the radio operator. Other equipment includes that which is necessary for maintaining listening watches on distress frequencies (e.g. watches indicating silent periods), VHF marine radio, aeronautic HF and VHF transreceivers, and the SOLAS HF telegraph transceiver, a non-direction beacon, an automatic direction finder, portable life boat SOLAS equipment, and equipment needed for internal

communications. The VHF marine radiotelephone system usually is a transreceiver with transmit power capability of less than 100 watts and which has up to 50 channel capability. A whip antenna is used with automatic tuning capability; a spare antenna is usually provided. The VHF aeronautic radio telephone system is similar but with fewer channels and no spare antenna is normally provided.

The internal communications services provided on a drilling unit ususally include the following:

- Audio and visual public address systems and alarms
- Internal telephone communications with patching to the external links
- A separate VHF radio system (using portable equipment) for crane cab communications to provide safe communications between cranes and supply boats.

Additionally, a VHF paging service may be provided along with a separate drillers intercoom. Emergency locator beacons (121.5 MHz and 243 MHz frequencies) are provided for the rig and lifeboats. Lifeboats contain a full complement of SOLAS convention equipment.

It is a common practice to fit a shore-station with equipment identical to that provided on a drilling unit which is essential for external communications. This includes MF/HF and VHF marine/aeronautic transreceivers. Thus, the equipment installed on a shore-station may consist of 500 to 1.5 kw transmitters (linear power amplifiers) connected to one or more antennas which differ from station to station. Separate receivers tuned to each of the assigned frequencies are installed at most stations and they are connected to either a common transmit-receive antenna or a separate receiving antenna. The following types of antennas (Petrie and Campbell, 1974) are used for transmission and reception:

a) Single horizontal dipole (wire) mounted about 50 ft (17 m) above ground and tuned with an antenna matching unit to operate on several frequencies;

b) Several half-wave dipoles with a common feed point which is located about 20 ft (7 m) above ground; these are designed to operate on several frequencies;

c) Several half-wave dipoles mounted about a quarter-wave length above ground, each for operation on a specific frequency; and

d) A single vertical monopole about a quarter-wave in length with a ground screen designed to operate on an assigned frequency near 2 MHz.

The purpose of an extensive antenna installation at a shore-station is to compensate for the short-comings of antennas fitted on a drilling unit. On a drilling unit space is limited which means that only a few antennas can be used. Moreover, due to the changing orientation of a drilling unit, a vertical whip which provides omni-directional radiation pattern is preferrable. In contrast, the shore-station antenna installations can be optimized, i.e. improved gain and directivity characteristics are achieved. Because of its possible large extent, a shore-base antenna installation is usually provided in a remote location with controlling and information transfer capability from a business office available through land lines or cables or a VHF link. The business office itself may also be equipped with a vertical whip and wire antennas which may act as a back up. In addition, the business office may be connected to a dock office which may have an additional set of antennas to monitor activities of support vessels.

The support vessels are fitted with equipment similar to that available on a drilling unit. These contain a VHF marine circuit and a HF circuit. The transmit powers for HF installations vary from 100 to 400 and those for VHF equipment is typically around 25 watts. Again, vertical whip and horizontal wire antennas are used with whips being more common. The antenna lengths are usually less than 10 m and a spare antenna is often provided. The radio equipment is placed on the bridge.

Helicopters are usually fitted with one VHF-AM (aeronautical band at 122 MHz or 123 MHz) transreceiver and sometimes, in addition, one

VHF-FM (marine band from 156 to 174 MHz) transreceiver. The VHF marine transmitter usually has a high power of 5 watts and a low power of 1 watt while the aeronautic transmitter has a 20 watt power. Some helicopters may be fitted with an additional aeronautic band VHF radio and/or an HF transreceiver. All these circuits are provided for voice communication.

It appears that two components belonging to two separate networks do not have a common private frequency assignment for exclusive use. However, any two components of two different networks can communicate with each other through frequencies designated for public correspondence. For example, the VHF marine bands contain no private frequencies, and thus several frequencies are designated for public use (ship/shore and intership communications). Similarly, several frequencies are designated for public correspondence in the MF/HF bands. The usual practice is to utilize the internationally designated distress and calling frequencies (e.g. 2182 KHz and 156.8 MHz, 500 KHz) to establish communications and once a particular link is established to switch to a frequency mutually agreed upon. At least these frequencies are continously monitored by offshore users and equipment of sufficient flexibility is available to monitor other public correspondence frequencies. It is also possible to establish contact through using the Coast Guard stations as intermediators. These stations can also assign a frequency for temporary use by two private parties.

Due to the possible sensitivity of the information communicated in an exploration drilling, it is common to use scramblers to achieve secure and confidential circuits. As noted earlier, equipment is installed to transmit and receive teletype and telecopier messages between a drill unit and a shore station. The teletype machines use established techniques or procedures to achieve low error rate in message transmission or reception due to long propagation paths which at MF/HF bands may significantly affect the message quality (signal to noise ratio). Several methods such as Forward Error Correcting (FEC) and Automatic Request for Repetitions (ARQ) are used in commercially available equipment. All the ship station installations comply with

the Canadian and at least the SOLAS conventions while all the shore stations meet the Canadian regulation standards. This ensures the adequacy of radio operator certificates (Canadian authorities are in a process of revising requirements, especially applicable to mobile offshore drilling units).

It appears from responces to our questionnaire and from our own observations that significant delay may sometime occur in affecting repairs to communication equipment. Moreover, the unavailability of qualified technicians may result in equipment downtime. No preventive or regular maintenance schedule is apparently followed and repair logs are not being kept. In addition, performance or diagnostic monitoring equipment is not in use.

5.0 ASSESSMENT OF STUDY AREA MEANS OF COMMUNICATION

5.1 Possible Causes of Failure

The conditions which could result in the failure or break-down of an external communication link are:

i) extremely adverse environmental condition,
ii) equipment break-down,
iii) power failure, and,
iv) electromagnetic interference.

The pertinent environmental conditions are heavy precipitation (rain or snow), high sea states (ocean waves induced by winds), and the presence of extensive sea ice along the communication path. The occurence and severity of these conditions in the study area have been given in Tables 1 to 4. These conditions affect the communication quality (signal-to-noise ratio) and, thus, determine the reliability (percentage of time a particular signal-to-noise ratio is exceeded) of a particular communication link. The occurrence of thunderstorm conditions in the study area can be as much as 3 to 4% in an extreme month, or approximately less than 24 hours in a month. The maximum percentage frequency of gale force winds (greater than or equal to 34 kts) in a month is about 8 which corresponds to a duration of approximately 48 hours. Storms (winds of 60-70 kt) in the study area average once a year and may last for several days.

Equipment break-down or failure may occur due to a faulty component and when a spare is unavailable. Lack of a spare component, and the delay in obtaining it, is apparently a common occurence. In some other instances equipment repair may not be possible without expert help due to the difficulty of even identifying the source of a problem or localization of a fault.

The power failure is less of a problem due to the availability of back-up or emergency power from storage batteries. The emergency power, although of limited wattage, is designed to last from 20 to 40

hours depending on the installation. Similarly, electromagnetic interference due to emission from other sources is not a major problem in the study area as yet due to the present limited exploration activity in individual regions. A substantial increase in communications traffic or spectrum congestion due to an increase in exploration activity may pose problems in the future. Significant electromagnetic interference is obviously possible during a war situation or due to a deliberate attempt of an enemy (e.g. through jamming). It should be noted that there are some other conditions (e.g. variations in the ionosphere which result in signal fading) which obviously affect communications quality or reliability. These conditions determine the inherent reliability of a communication link and, thus, are not included in the four external causes for a link break-down identified earlier. These conditions though may equally result in the failure of a communication link which may last from few minutes to several hours.

The main conditions which result in the failure of an internal communications link on a drilling unit are equipment break-down and power failure. Intrinsically safe equipment (e.g. fire proofed, hand-operated telephones) offer obvious advantages. The noise level at a particular place may prevent comprehension of voice communications some times, which makes desireable the use of visual alarms during emergency situations, in addition to audio alarms.

5.2 Assessment

It is desireable that communications links among components of a "drilling system" be maintained all the time (at least communications between two components be possible when required); i.e. there should be no break-down in the offshore communication network. The typical operational reliability of MF, HF, and VHF links employed by communications users in the study area during day, night, or storm conditions is summarized in Table 13. These values are largely based on responses from the questions sent to offshore exploration companies and the coast guard, and are in general agreement with those available in the literature.

Frequency	Day	Night	Storm
2 Mhz	90	40	10
4 Mhz	90	90	15
6 Mhz	85	30	20
8 Mhz	90	75	50
Above 10 Mhz	85	10	10
VHF-FM	95	95	85
VHF-AM	95	95	75
SATCOM	99	99	99

TABLE 13. Typical Operational Reliability (percentage) of Various Communications Links in the Study Area

The VHF and higher frequency (e.g., UHF) links used for line-of-sight distances are inherently highly reliable. The VHF band is immune to most atmospheric noises and due to its line-of-sight limitations is relatively interference free. Thus, reliable communications extend approximately to 75 km with coverage frequently extending to 90 km. The VHF coverage areas of coast guard stations depicted in Figure 8, extend up to a distance of 40 miles (64 km) offshore. Infrequently, temperature inversions in the atmosphere may produce skip conditions for short periods, extending up to a few days, during which VHF communications can occur even up to a distance of 400 km.

As noted before, the MF and HF frequency bands used for medium to long range communications between ship and shore stations are inherently less reliable than the VHF links. These bands are subject to severe atmospheric disturbances during abnormal weather conditions. The ground wave mode of communications is normally more reliable than the sky wave mode. During severe environmental conditions such as lightning, rain and wind storms, the band is subject to heavy static and other noises. The noise may be severe enough to reduce the effective coverage of the coast guard stations. The station coverage may be further reduced during night when noise from sky wave is added to the ground wav noise. The MF coverage area of coast guard stations (Figure 8) extends to only 150 miles (240 km) offshore, perhaps indicating the range of reliable MF communications.

To deduce the effect of high winds on offshore communications using MF and HF ground waves, signal to noise computations were performed by Mr. Barry Dawe, a post-graduate engineering student at the Memorial University of Newfoundland (MUN) under Professor John Walsh's direction. These computations were performed using an attenuation function computer program available at MUN. The ratio of power received, P_r, to transmit power, P_t, over a communication path is given by

$$\frac{P_r}{P_t} = \frac{4\lambda^2 G_r G_t W^2}{(4\pi)^2 R^2} = TL$$

where, G_r and G_t are, respectively, the antenna gains of the receiver and transmitter, λ is the wavelength, R is the range or distance, and W is the attenuation function. Signal-to-Noise ratios (S/N) and communication reliability results obtained for typical MF and HF frequencies used in the study area are given in Table 14. The S/N values at the receiver output were assumed to be equal to the signal-to-noise ratio at the receiver input (i.e., receiver noise and antenna losses were neglected). Thus, the S/N values given in Table 14, correspond to P_r/N values, where P_r was computed from the above equation for a transmit power of 1000 watts (1 kw). The values of noise, N, were taken from the reference man-made noise data contained in the International Radio Consultative committee (CCIR) Report No. 258.4. The specified noise values for rigs are those for heavy industrial locations, which are significantly higher than for a non-industrial shore location. The atmospheric noise data obtained from the CCIR Report No. 312 indicated that the S/N values given in Table 14 may be degraded during summer conditions by an average of 6 db.

The results shown in Table 14 were obtained by assuming a $\lambda/4$ (quarter wave) whip antenna at a frequency of 7.48 MHz providing a directive gain of 5.15 dB. The antenna gain was degraded with frequency by assuming the gain of a unit dipole to be 1.70 dB. The shore based installation was assumed to be at an elevation of 600 ft containing two $\lambda/4$ whip antennas at 7.418 MHz spaced $\lambda/2$ apart, which provided a combined gain of 8.15 dB (3dB increase in gain over a simple element). As antenna values correspond for perfect ground, a 2 dB ground loss was assumed. The attenuation function was calculated using the MUN software while the modified surface impedance values were computed using a method, developed by Mr. S. Srivastava, (also a post-graduate engineering student at MUN), which is comparable to that available in the literature.

The results of Table 14 indicate that, theoretically, voice and telex reception quality for transmissions at 2 and 3 MHz, using ground-waves, is adequate for distances up to 450 km under winds of up to gale force intensity (approximately 34 kt). This is true assuming that the criteria used be of signal to noise ratio exceeding 14 db for

MF/HF Band Frequencies (MHZ)	Background Man-Made Noise ($x10^{-12}$ W)		Wind (kt)	S/N (dB) at Distance		Max Distance (km) For Telex Communication (S/N = 2dB)
	Rig	Shore		300 km	450 km	
2.398	42	5	10 30 50	50 15 10	40 -6 -16	1109 450 380
3.396	16	2	10 30 50	50 27 3	40 9 -20	993 502 296
4.588	7	1	10 30 50	50 18 -17	39 -8 -42	947 383 177
5.390	5	.5	10 30 50	49 15 -17	37 -11 -43	881 366 190
6.855	2	.2	10 30 50	42 2 -10	25 -25 -38	663 295 233
7.418	2	.2	10 30 50	40 -3 -9	23 -31 -38	626 267 236

TABLE 14. Estimated Signal-to-Noise Ratio (S/N) For Shore to Rig Communications at Typical MF/HF Frequencies (Needed S/N for Reception Quality; Broadcast greater than 38dB, Intelligible Voice greater than 14dB; Telex greater than 2dB)

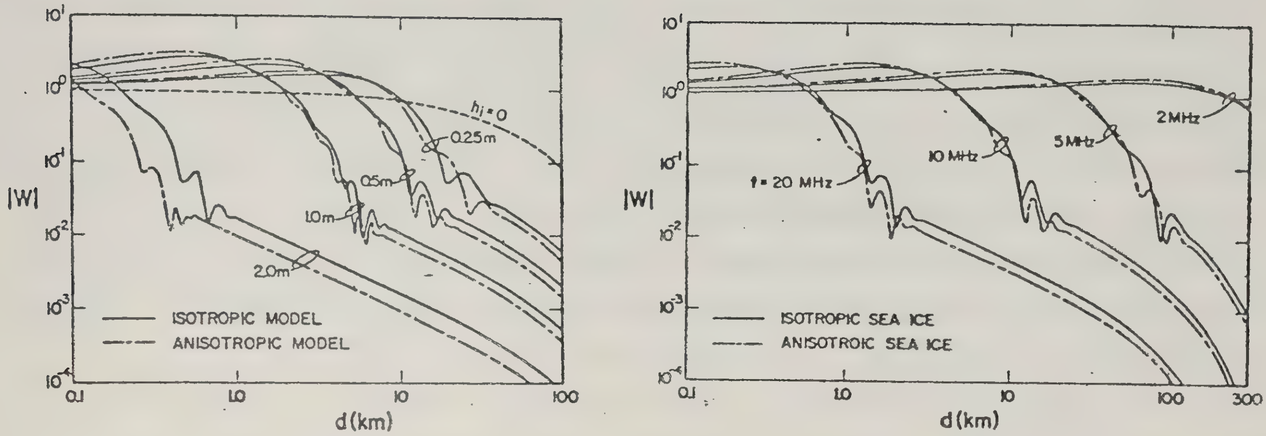
teletype or telex messages. The maximum range, at 50 kt winds (significantly less than the expected storm force winds of 60-70 kt) for telex quality reception (signal to noise equal to 2 db) is 380 km and the maximum range for voice quality receptions is expected to be significantly less than this. The maximum range values of Table 14 were obtained by determining the ratio W /R required to meet a given signal to noise ratio (2db in this case) and subsequently determining R (range) which would satisfy this ratio using the spherical earth attenuation program available at MUN (W is also a function of R).

The path or transmission losses at distances of 300 km and 450 km, respectively, ranged in values from 84 to 160 db and from 93.5 to 186 db. The corresponding values of the attenuation function ranged from 0.4 to 1.9 X 10^{-4} and 0.2 to 8 X 10^{-6} (smaller values mean smaller signal strengths at the receiver).

The variations in the attenuation function (both magnitude and phase) for transmissions over sea ice and over mixed sea to sea ice paths with variations in distance, frequency, ice thickness, and elevation have been studied by Hill and Wait (1981a and b). Examples of their results are shown in Figures 19 and 20 which indicate that at a frequency of 2 MHz transmissions over a sea ice path may even be beneficial. However, at higher frequencies the value of attenuation function may be comparable to those obtained for gale force winds, thus, significantly reducing the effective communications range and affecting link reliability.

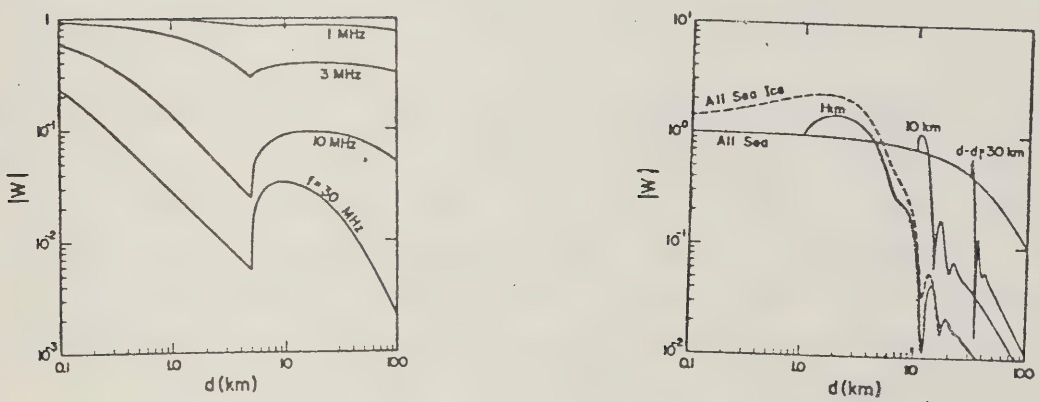
In summary, the practically effective and reliable range of a VHF link appear to be about 80 km and those of MF or HF links, which principally use ground-wave made of propagation, to be up to approximately 350 km. Considerably larger distances are possible with sky-wave mode of propagation but those links must be considered less reliable. Satellite communication links are inherently highly reliable.

The drilling units operating in the study area have channel redundancy within a frequency band and practically all employ frequency band redundancy. Almost all drilling units have satellite communications terminals. Moreover, the communications equipment



(a) (b)

FIGURE 19. Magnitude of the Attentuation Function as a Function of Range (a) for Various Sea Ice Thicknesses h_i at 10 MHZ and (b) for Various Frequencies at (h_i=0.5m) (From Hill and Wait, 1981a)



(a) (b)

FIGURE 20. Magnitude of the Attenuation Function for (a) Land-to-Sea Path for Various Frequencies (Land Distance = 5 km) and (b) Sea-to-Sea Ice Path for Various Lengths of the Sea Section ($d-d_1$=1,10,30 km)

(From Hill and Wait, 1981b)

onboard the drilling unit normally includes redundant antennas, transmitters and receivers at least for the prime communication link with the shore-base. This link for operations on the Grand Banks and those on the Scotia Shelf is provided by MF/HF band frequencies. In such operations, the adequate reliability is only maintained by the provision of satellite communications facilities which also provide immediate access, emergency override, capability. The operations within approximately 80 km of Sable Island on the Scotian Shelf have access to the satellite station located on it through a reliable VHF link.

A helicopter flying at heights of 300 to 500 m can maintain VHF communications with ground stations for distances up to 100 km. Thus, while transversing a distance of 500 km (e.g. between a shore-base and a drilling unit), it is in contact with a ground station for about half the distance using the VHF link. It is only for the middle half distances that it may have to utilize the HF link, if so required. At speeds of about 100 km per hour, this implies a lower communication reliability for a period of about 2 hours.

The above discussion related to helicopter communications is applicable to support vessels as well. While a support vessel is travelling between a drilling unit and a shore-base apart at a distance of 500 km, it is out of the reliable or effective range of the VHF marine link for about two thirds of the distance in the middle. At a speed of about 10 knots, this means that it has to rely on MF or HF communications for less than 15 hours.

It should be noted that the distress link at 500 KHz is very reliable and is available on drill units, support vessels, and lifeboats. Thus, emergency communications are possible at any time, if needed from these stations.

The possibility of communications between various components of two nearby networks is readily apparent. At both MF/HF and VHF marine band frequencies a number of public correspondence intership or ship/shore frequencies are available. Moreover, a communication link can be established by using the international distress or calling frequency and then subsequently switching to a working frequency.

Thus, the offshore communications in the study area at present are practically reliable and appear to be adequate to meet the needs of exploration companies. This reliability can be enhanced by following a frequent preventive maintenance schedule for the communications equipment and a required provisioning of basic spare components. In addition, it would be desireable to have available, at least with the drilling unit, a qualified technician capable of repairing communications equipment. A communications contingency plan should be prepared and made available to radio operators outlining the procedures for using communications equipment in the event of a link breakdown following the causes stated in the preceeding section.

6.0 OTHER COMMUNICATIONS SYSTEMS

6.1 Other Offshore Areas

Other offshore areas employ communications systems similar to those being utilized in the study area. As noted earlier, exploration activities in most other offshore regions are being undertaken in areas close to the shore (distances less than 100 km). This means that the VHF band is the prime means of communication. For example, in Beaufort Sea operations both VHF and HF bands are being used for drilling activities which are about 80-120 km offshore. Satellite communication is also being utilized along with microwave links to allow communications between shorebases.

Only communications systems in North Sea operations differs from those in the study area and elsewhere. As noted earlier the required communications ranges for the North Sea and the environmental conditions prevailing are comparable to those relevant in the study area. Early in 1965 when oil exploration in the North Sea got underway, the new communications demands for the British Sector were met by expanding the number of channels in the 2-4 MHz band available from coast radio stations. This augmented service by the British Post office to the rigs provides five speech channels, which can be used on a shared basis, and includes aproximately 90 dedicated teleprinter channels which can be equipped with error correcting devices and routed to specific inland business addresses (Hill, 1980; Hyatt, 1980).

The above rig service for the exploration activity is still in operation today, even though, in the later exploration stages spectrum congestion and channel interference became a major problem. Thus, for maximum frequency spectrum economy, an independent side band system (instead of a double side band emission) was soon adopted with the lower side band carrying one telephone channel shared between the rigs using the system and the uppere sideband carrying a multi-channel system having a capacity of up to 15 teleprinter channels. It was also soon realized that offshore production platforms would require a more

permanent communications network, submarine cables were considered but rejected for reasons of high cost and their possible vulnerability near offshore platforms. It was thought that satellite communications would not be available in time so trans-horizon radio using tropospheric scatter (tropo-scatter), with multichannel capacity was chosen by the British office.

A tropo-scatter system, as the name suggests, utilizes scattering properties of the troposphere to propagate weak but reliable signals several hundred miles beyond the horizon in the VHF, UHF, and SHF bands. The British trans-horizon radio links operate in either the 2.5 or 2 GHz bands and are configured on a quadruple diversity basis using space and polarization and a triangulated system to achieve four independent radio signal paths. Thus, four antennas (with a switching capacity) are used at the shore-base, each 12 to 18 m in diameter. Two of the antennas are connected to one platform and the other two antennas to the second platform through troposcatter links. The two offshore platforms are connected through a line of sight microwave link. Transmitter rated at at 1 kw output power are used. Typical antenna diameters on offshore terminals is from 6 to 8 m.

An important parameter in tropo-scatter propagation is the scatter angle or angle of intersection of the transmitting and receiving antenna beams. As narrow beam directional antennas are used in tropo-scatter systems, the orientation of the antennas on the drilling unit would have to automatically controlled or stabilized to provide communications when the drilling unit is under tow or during rough sea conditions. This antenna stabilization requirement is similar to that needed for communicating with the ANIK satellite. Even if possible, such a complex antenna installation on the drilling units and on the shorestation would be expensive. Thus, the tropo-scatter communications system is not a practical and economically viable option for offshore exploration communications in the study area unless fixed offshore platforms are used and there is a substantial density of exploration activity.

6.2 Systems Under Development

Among the other possible systems is the system known as meteor-burst propagation system. Frequencies in the VHF and UHF bands may be propagated by reflection from columns of ionization produced by meters entering the lower E region. Experimental single channel 2-way telegraph circuits have been operated over distances of 800 to 2000 km using frequencies in the range from 30 to 40 MHz and with transmitter powers of 1 to 3 kw. One-way transmission of voice and facsimile have also been conducted using transmitter powers of 1 and 20 kw, respectively. The frequency range from about 50 to 80 MHz appears to be best suited for meteor-burst transmission. The exact reliability of this type of transmission is not known but is unlikely to be better than HF sky-wave propagation.

Two relevant systems under consideration by the Department of Communications (DOC) are the RACE System (Radio Telephone with Automatic Channel Evaluation) and the M-SAT (Mobile Satellite). RACE is a HF Radio Telephone system designed by DOC, and being manufactured by Canadian Marconi, which is intended to extend the coverage of the switched telephone system to remote communities, mining camps, drilling rigs, and ships on the high seas. The system is as easy to use and operates in the same manner as a conventional telephone. In field trials carried out during 1980 and 1981, a call success rate of over 98 percent has been demonstrated. The reliability is achieved through the use of a microprocessor which controls the radio and automatically selects the optimal frequency channel to establish communications. However, RACE does not appear to be capable of providing high quality voice or data circuits; significantly lesser quality is achieved in comparison with satellite or even VHF communication (Tarrant, 1983).

The Communications Research Centre of the DOC has also recently developed a low cost; HF message terminal which could substantially improve intership and ship-to-shore communications. This new terminal is designed to augment the capability of existing HF radios by allowing the transmissions of text messages over vast distances when

radio propagation conditions are too adverse to permit intelligible voice transmissions. The terminal has been successfully field tested and is expected to commercially available soon. The Canadian Department of Communications has plans to introduce a new satellite system, called Mobil Satellite (MSAT), which would provide mobile communications to the non-urban centres of Canada. This service will provide a high quality mobile service up to 200-250 miles offshore on the east coast (coverage dependent on satellite antenna foot-print) allowing both intership and shipshore communications. MSAT is expected to operate in the 8.00 MHz band and is being designed to provide mobile telephone, radio, paging, and data services at a reasonably low cost using portable satellite terminals which have very small antennas (less than 1 m). The feasibility and design study is anticipated to last until 1986 with a demonstration satellite expected to be in service from 1986 to 1994. The commercial service is being planned after 1994.

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APPENDIX A

TERMS OF REFERENCE

APPENDIX "A"
STATEMENT OF WORK

INTRODUCTION

The Royal Commission on the Ocean Ranger Marine Disaster has been given comprehensive Terms of Reference which are divided into two parts.

Part One calls for an extensive investigation into the loss of the drill rig, Ocean Ranger. This inquiry has been underway since the Commission was jointly established in March 1982 by the governments of Canada and Newfoundland and Labrador.

Part Two of the Commission's Terms of Reference call for it to "inquire into, report upon, and make recommendations with respect to" both the marine and drilling aspects of practices and procedures in respect of Eastern Canadian Offshore drilling operations and to a number of specific matters relating to drilling units operating offshore.

To address the Part Two Terms of Reference, the Commission is undertaking a study program the goal of which is to identify practical means of improving the safety of Eastern Canada Offshore drilling operations.

The study area is Eastern Canadian Offshore extending from the shoreline to the limits of jurisdictional claims. The area extends from the Canada-US boundary north to the limit of areas which will be serviced from East Coast ports and use marine drilling systems (approximately 75°N).

The subject of study is offshore exploration and delineation drilling operations, including service and supply (marine and air) activities

The issue is human safety. Property safety will be considered to the extent it affects human safety. Environmental safety will be addressed by a State of the Art Review.

The Part Two Study Plan will include the following areas:

1. Environment

This study area will address the physical environment conditions within which offshore drilling operations take place. Emphasis will be placed on severe and limiting conditions and their detection or prediction.

2. Regulation

This study area will address the manner in which offshore drilling operations are controlled by rules, regulations, and guidelines and their relationship to safety. Emphasis will be on government control, but included will be industry control.

3. Design

This study area addresses the process of conception, design, construction, classification, and certification of structures and equipment used in offshore drilling operations. It will include consideration of operational limitations and upkeep requirements.

4. Safety

This study area focuses on elements of offshore drilling operations directly related to establishment and maintenance of personnel safety. It includes the identification of levels of risk for various activities. It deals with workplace health and safety. In particular it will address systems to ensure survival and

minimize injury resulting from unplanned events. Special focus will be given to systems of evacuation, survival and recovery, including self help as well as external assistance.

5. Training

To evaluate and, as appropriate, recommend improvements to operational marine and safety training for the Eastern Canadian offshore petroleum industry and related sectors.

STUDY OBJECTIVE

To assess critically the means for communication in relation to safe operation of Eastern Canada offshore exploratory drilling and to provide a perspective on practical possibilities to improve these means should they be found to be deficient.

Definitions

Drilling System - refers to a drilling unit and the support facilities such as support vessels, transport helicopters, and shore bases assigned to that particular drilling unit.

Means of Communication - refers to the communications hardware used to transmit information from place to place by verbal, written, or other means.

SCOPE

This study will examine the communications systems currently in use for Eastern Canada offshore drilling units, support vessels, transport helicopters, and at shore support bases. Both internal and external communications systems will be examined; and an assessment will be made of their adequacy to ensure safe operations in terms of information transmittal capability, reliability, ease of use, physical location of the equipment, compatability of the systems, and special training required for use.

An evaluation will be made of the reliability of communications systems to ensure their proper operation during an emergency event, including a condition involving a partial or total failure of a communication system. The conditions which could lead to the failure of the individual communications systems will be examined and documented.

The study will examine communications systems in use in the offshore drilling industry and in other offshore industries in other areas of the world as well as systems which are being developed to determine their applicability and effectiveness in the Eastern Canada offshore.

TASK DESCRIPTION

The contractor will undertake a review of the communications systems currently in use in Eastern Canada offshore exploratory drilling.

The internal communications system of drilling units presently in use and the external communications systems of drilling units, support vessels, transport helicopters and shore bases will be examined; and a description of these communications systems will be provided.

The described communications systems will be evaluated, and an assessment will be made of their individual suitability in terms of:

1. the required quality and quantity of transmissions
2. reliability

3. ease of use
4. physical location of the equipment
5. compatability with other systems
6. training required to operate.

The total communications network associated with each "drilling system" (drilling unit, support vessels, transport helicopters, shore bases) will be examined; and an assessment will be made as to the effectiveness of the system in maintaining communications links between each component. The degree of redundancy inherent in the communications system will be identified; and an assessment will be made as to the conditions which could occur which would lead to a loss of communications between various components (ie. drilling unit and support vessel, shore base and support vessel, shore base and drilling unit, etc.).

Communications systems currently in use in the offshore drilling industry and in other offshore industries in other areas of the world will also be examined and evaluated using the same criteria as was used in the evaluation of systems currently in use in the Eastern Canada offshore. Systems currently being developed will also be examined and evaluated using these criteria.

An assessment will be made on the combination of the individual systems currently in use or under development which would provide the most "desirable" overall communications system for a "drilling system" in terms of information transmission, reliability, ease of use, physical location of equipment, compatability with other systems, and required training.

SCHEDULE

From the date of contract award, the report will be submitted in 12 weeks.

REPORT REQUIREMENTS

Ten copies of the draft final report will be provided. A single camera-ready copy of the final report will be provided.

The report format, type size, and spacing will adhere to Commission guidelines for appendix documents.

RELEASE OF REPORT

It is a policy of the Commission that reports submitted to it will be released to the public. These reports will be identified as exercises funded by the Commission but not necessarily representing the Commission's viewpoint. The timing of the release of these reports will be at the discretion of the Commission.